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Vol. 64 No. 384 OCTOBER, 1961 Monthly: Two Shillings and Sixpence

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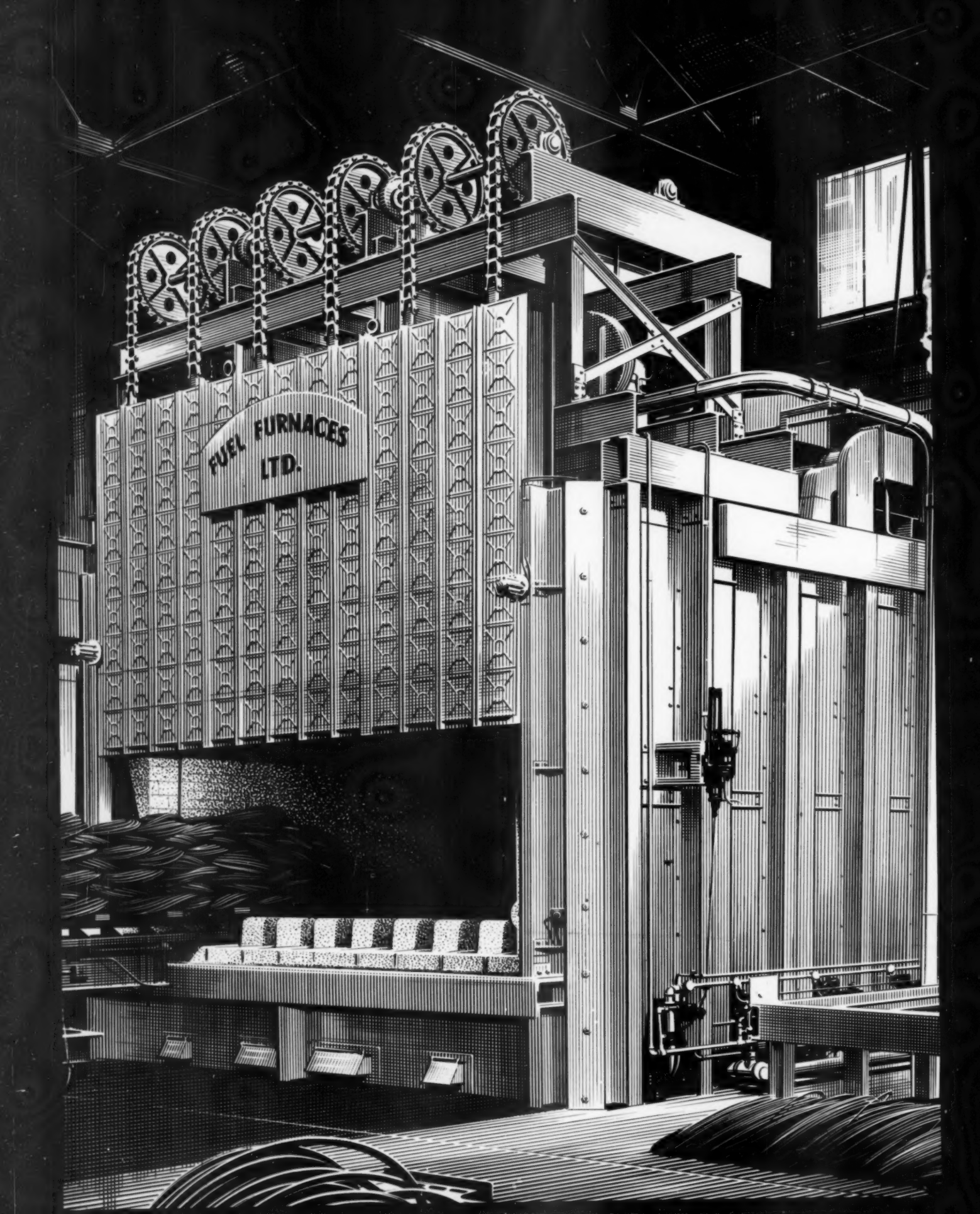
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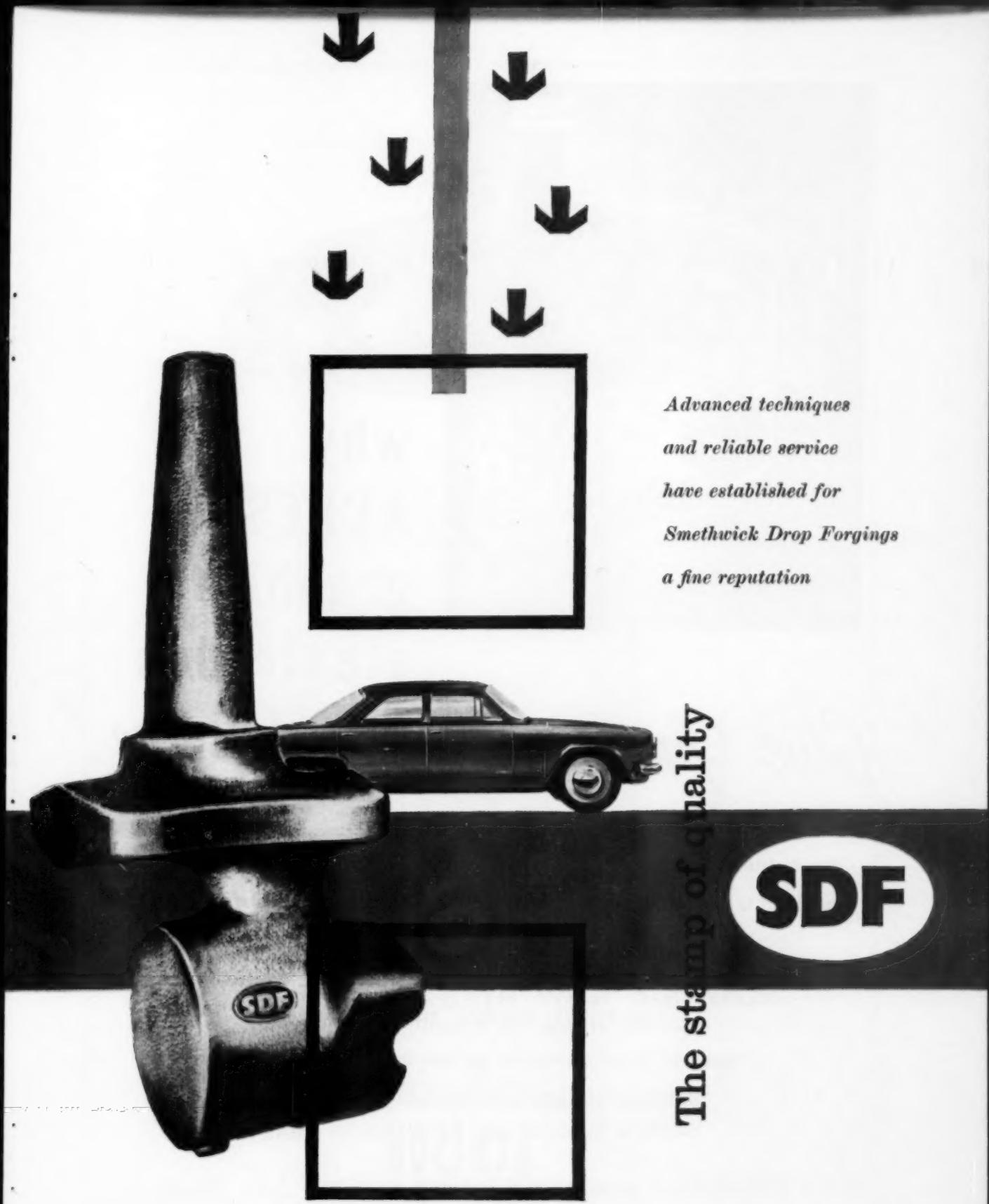

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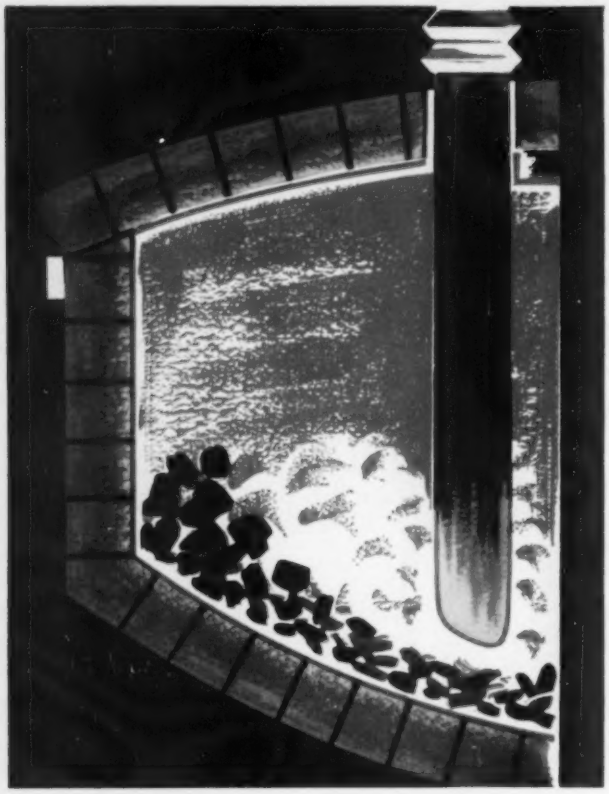

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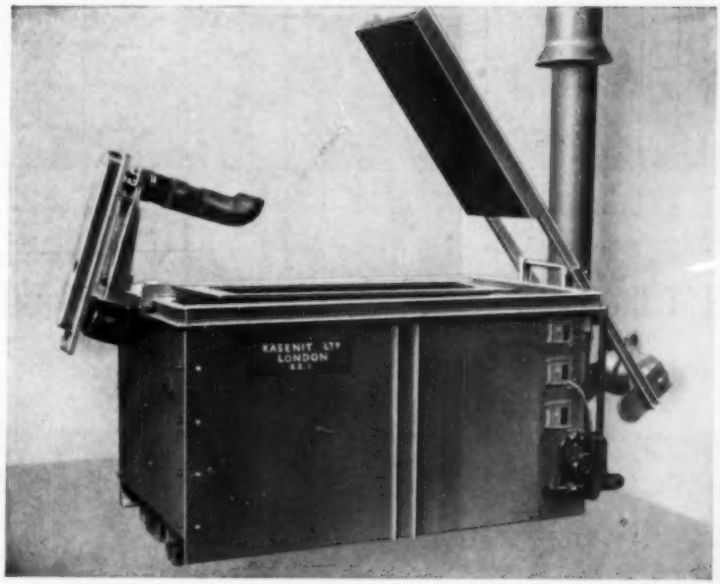

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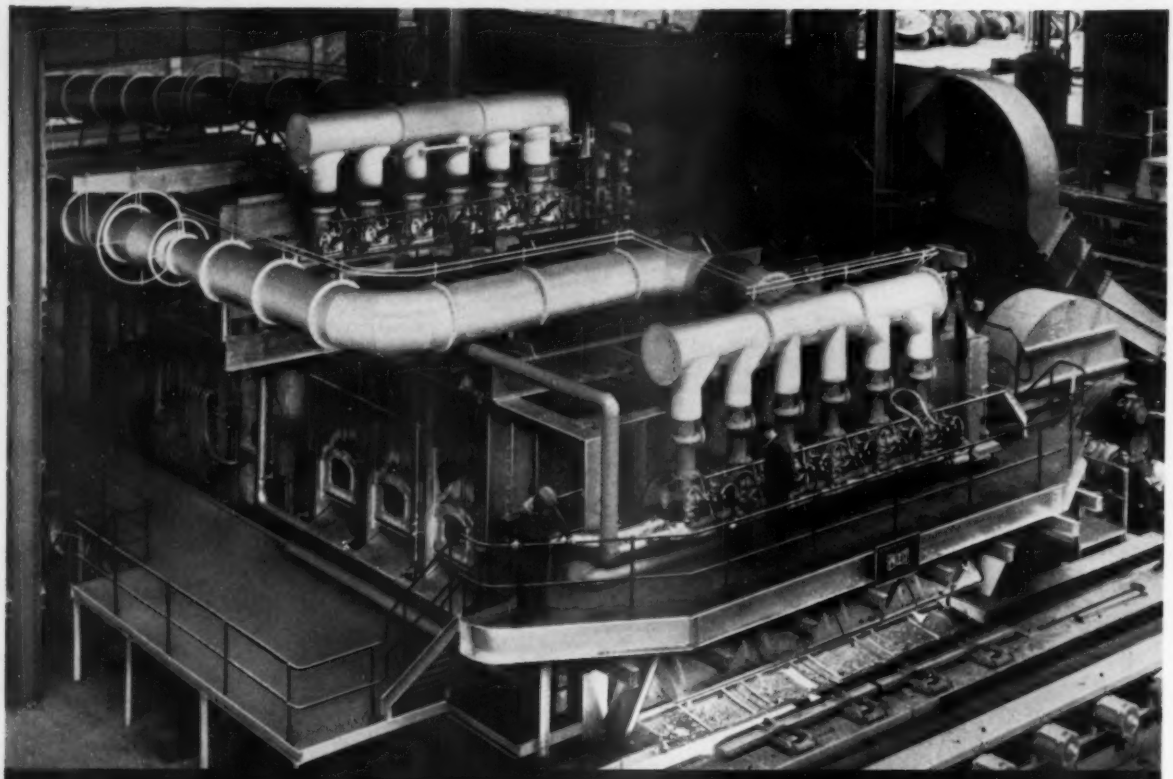

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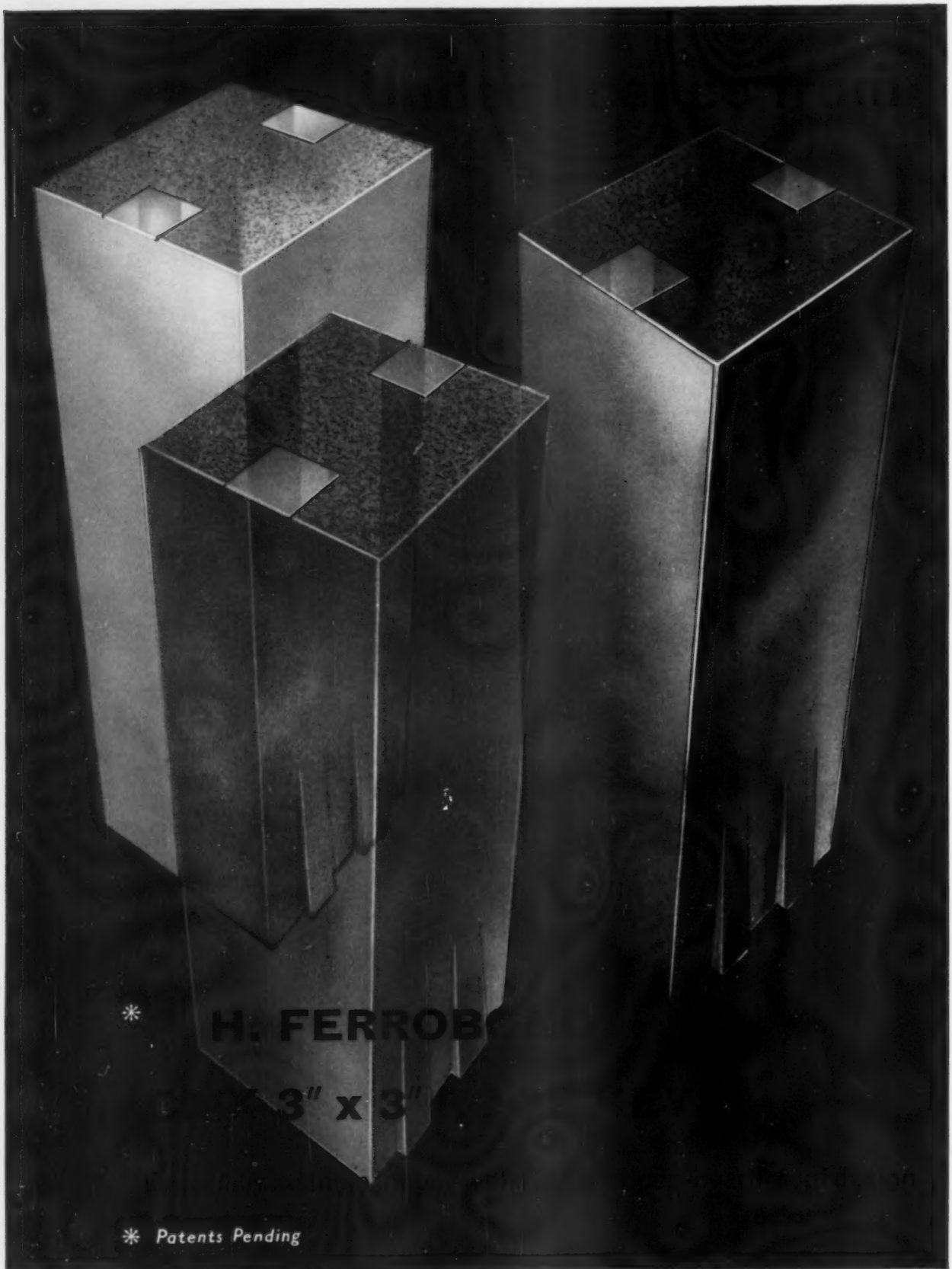

DA/7181

America, Pickford Holland are now making to-day's most successful basic roof keys

The P.H. Ferrobond CMX 3" x 3" Roof Key is a new, metal-clad, chemically bonded basic open-hearth brick without internal plates, designed by E. J. Lavino & Co. of Philadelphia for maximum service and economy. A series of comparative tests with internally plated 4½" x 3" keys proved Ferrobond to be always equal, and usually superior, in performance. They are light and easy to handle, have built-in hot face expansion, and tabs ensure correct alignment. In addition, saving on material cost by rib and valley construction makes the P.H. Ferrobond beyond doubt today's outstanding value in basic roof brick. Considering a trial? Send drawings of your present roof to Pickford Holland who will redesign to suit Ferrobond bricks, and give you the assistance of a service engineer for installation.

See how split-roof tests prove OUTSTANDING PERFORMANCE by new FERROBOND ROOF KEYS

Furnace Capacity	Construction of Roof	Campaign Life	Total Tonnage Produced	Tons/ Hour	% AREA PATCHED		Oxygen Lances through Roof
					Lavino Ferrobond CMX 3" x 3" Keys	Metal Cased Internally Reinforced 4½" x 3" Keys	
190 Tons	12" Rib 9" Valley	284 Heats 112 Days	54,000 Tons	20	1.8%	1.8%	2
190 Tons	12" Rib 9" Valley	250 Heats 75 Days	47,500 Tons	26	2.2%	12.8%	2
190 Tons	All 12"	405 Heats 130 Days	77,000 Tons	25	62%	67%	2
280 Tons	15" Rib 12" Valley	488 Heats 196 Days	100,000 Tons	21	2.8%	6.8%	NONE
345 Tons	15" Rib 12" Valley	453 Heats 170 Days	157,000 Tons	38.5	10.4%	19.0%	2
400 Tons	15" Rib 12" Valley	298 Heats 186 Days	120,000 Tons	27	NIL	NIL	2

This chart shows comparative performance records in North America of six typical open hearth roofs. In each case the roof was constructed half-and-half of Lavino Ferrobond CMX 3" x 3" Roof Keys and Internally Plated 4½" x 3" Roof Keys. All were of the Fairless type roof construction (hold-up, hold-down). Production rate of tons per hour is based on total production over campaign time, and includes repair times, fettling times, and all lost time whatever the cause.

P.H. Ferrobond Roof Keys are manufactured under licence from E. J. Lavino & Company, Philadelphia, U.S.A. by

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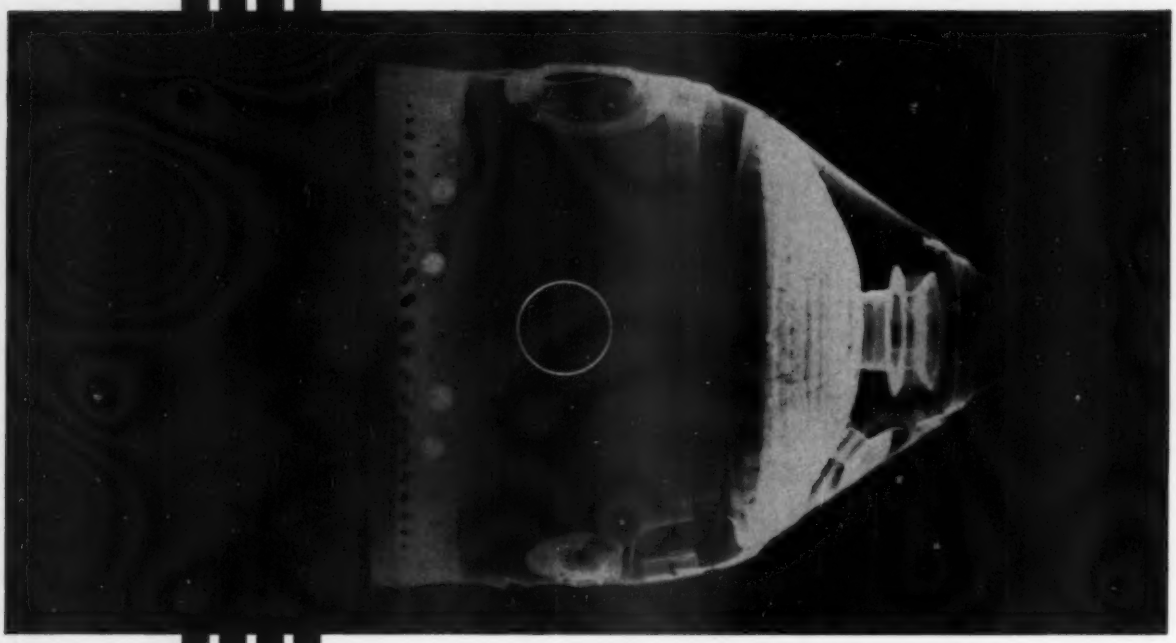

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The plant illustrated comprises three batch-type electrically heated furnaces, a 50-ton charging machine, loading and unloading racks and inert gas plant.

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NICHROME* V is an 80/20 nickel chromium alloy, with its main applications in high temperature heating elements working at up to 1,150°C—for example, in furnaces, cookers, electric fires and the like. Available in wire, ribbon, hot and cold rolled strip, hot rolled rounds and ribbon form, it is also made in superfine sizes, for use in precision resistors and where high ohmic value is needed.

NICHROME* 65/15 nickel-chromium, is the material for working temperatures of up to 950°C, and finds a place in many domestic appliances. Used in resistors and rheostats, it allows compact units, capable of withstanding, undamaged, severe overloads and short circuits. Corrosion resistant, it has many non-electrical applications and is available in the same forms as Nichrome* V.

CHROMAX*, made from 37% nickel, 18% chromium, 2% silicon, balance iron, is a material specifically designed for furnace elements and conveyor belts, and is made in appropriate forms. It is superior to 35/15 type alloys in strength at high temperatures and in resistance to carburisation and oxidation.

* *Regd. Trade Mark.*

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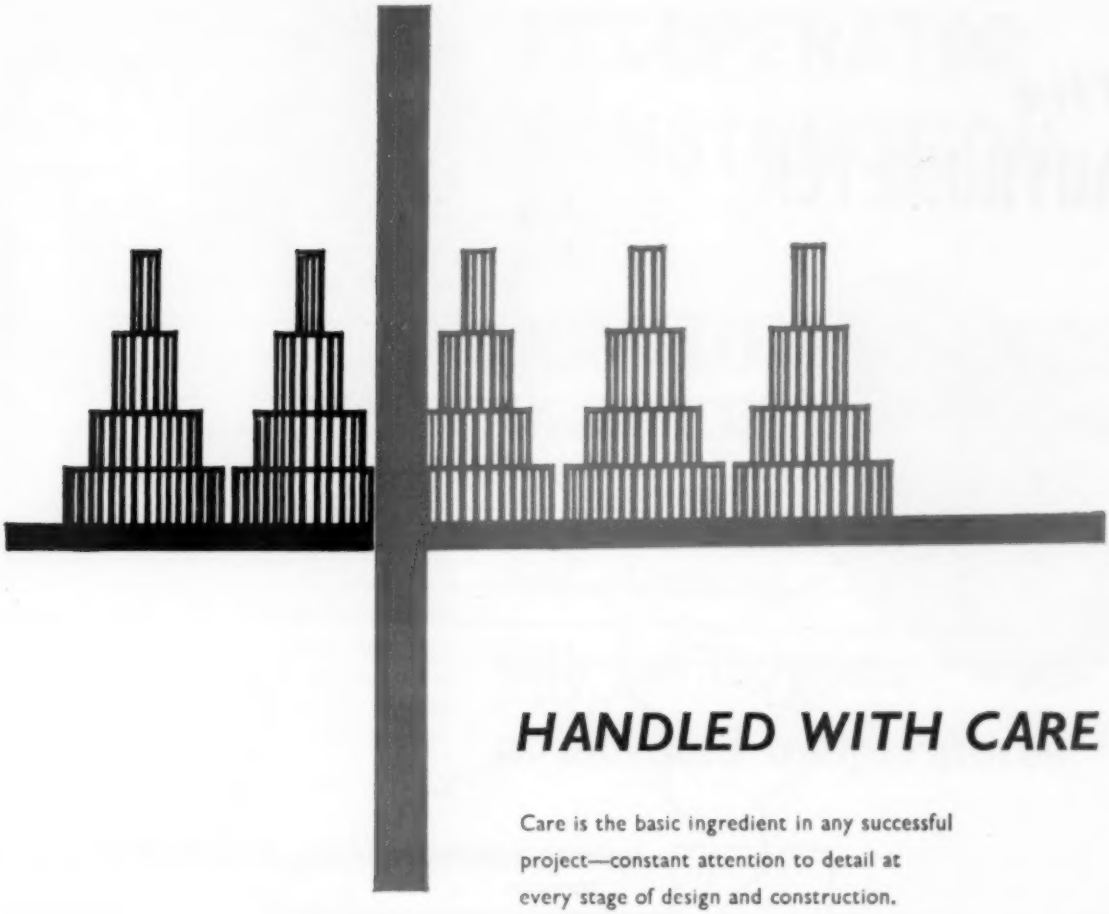
For further information on Nichrome V and Nichrome*, write for Data Sheet No. 5—a 24-page booklet.*



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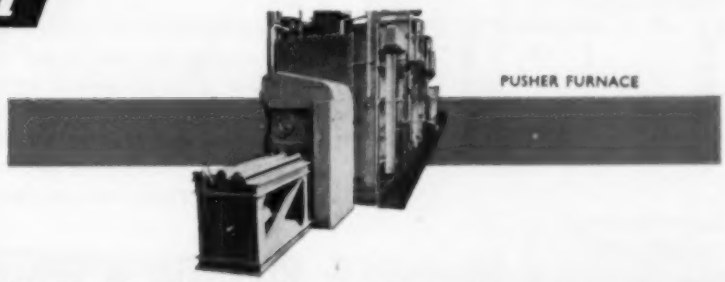

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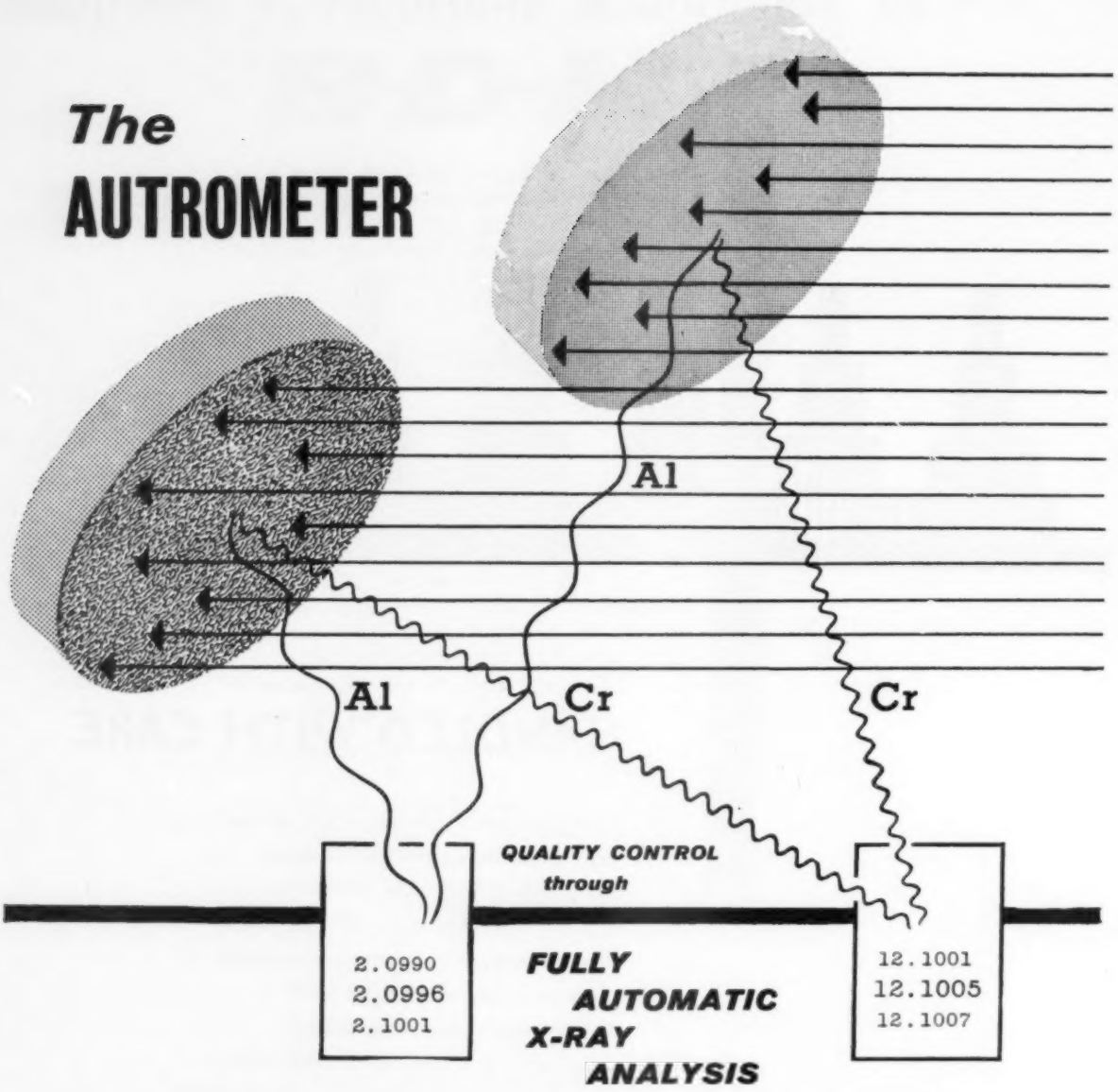

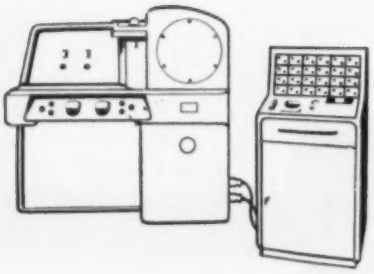

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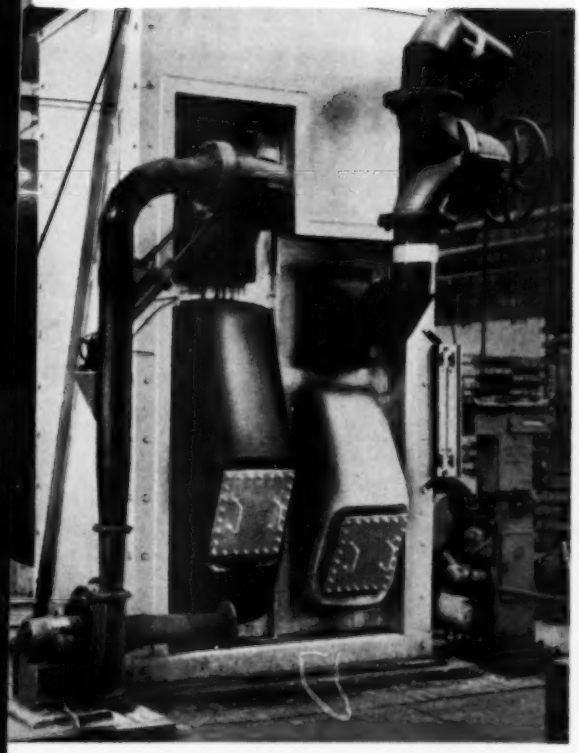
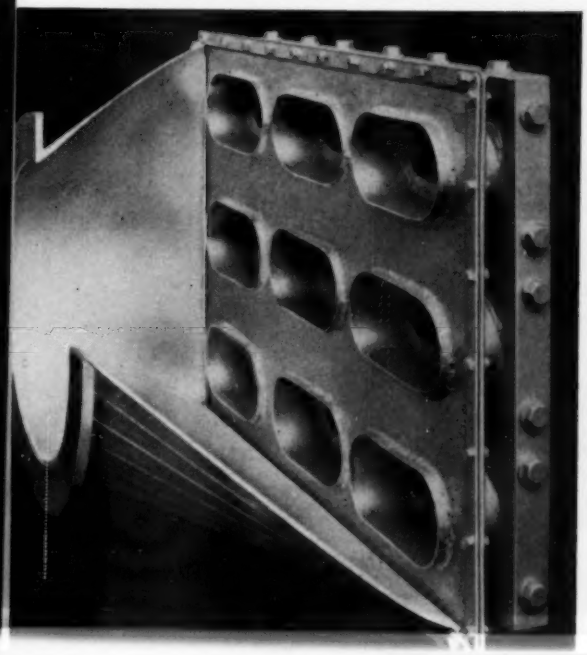


The Combined Newton Needle Air and Fuel Gas Recuperators shown above are installed on the Sterling Billet Heating Furnace at Messrs. Hadfields & Company Ltd, Sheffield, and incorporate this latest development in high pressure flexible-end connection.

IMPROVED RECUPERATOR CONSTRUCTION BY NEWTON CHAMBERS

Ensuring the accommodation of thermal expansion and stresses with gas tightness at elevated temperatures

Our portable demonstration model. The oval shape tubular steel inserts are cast into the end-supporting flanges as an integral part of each heat-resisting cast-iron heat exchanger element. The steel inserts are welded into a thin steel diaphragm plate to which are connected the air and fuel gas inlet and outlet ducts, a completely gas tight joint is then ensured.



The latest introduction by Newton Chambers of the flexible-end (D.B. type) connections for high pressure air and fuel gas recuperators are now available and can be demonstrated.

This type of construction successfully accommodates thermal extensions within recuperators when operated at temperatures of up to 1,050°C. on the exhaust furnace gas side, and up to 650°C. on the combustion air and fuel gas side.

We would welcome the opportunity to show you over installations now at work, and to discuss your recuperator problems with you.

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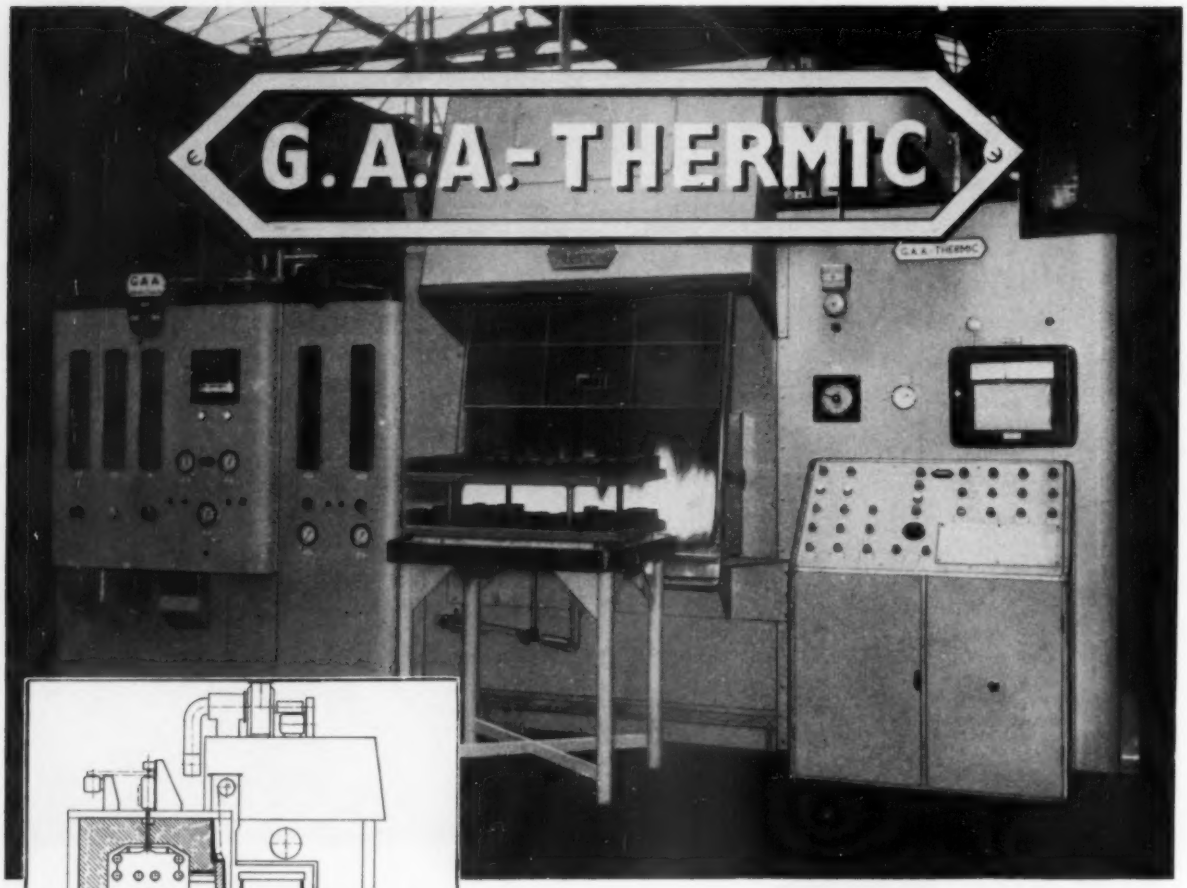

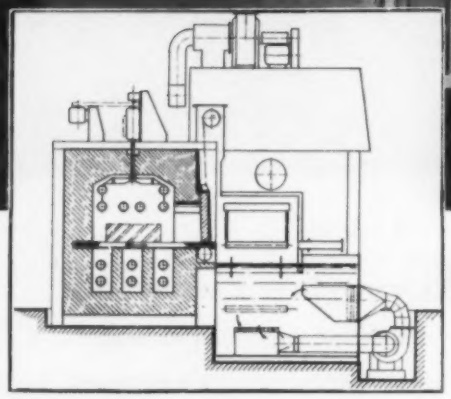

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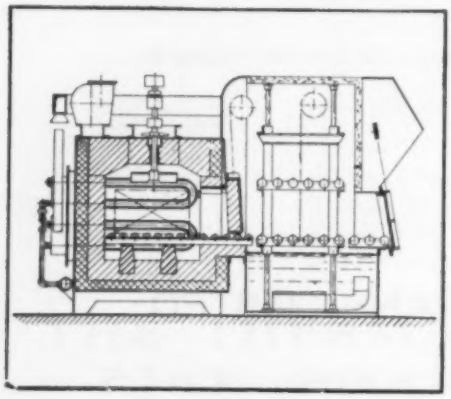

Alternatively Rotating Retort batch type equipment with "built-in" atmosphere control is available. Or pusher type furnaces for continuous production.

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He will tell you that their performance is excellent; that their taper-threading gives stronger joints; that they cut down repair time—drastically; and that they are backed by a service as quick as it is reliable.

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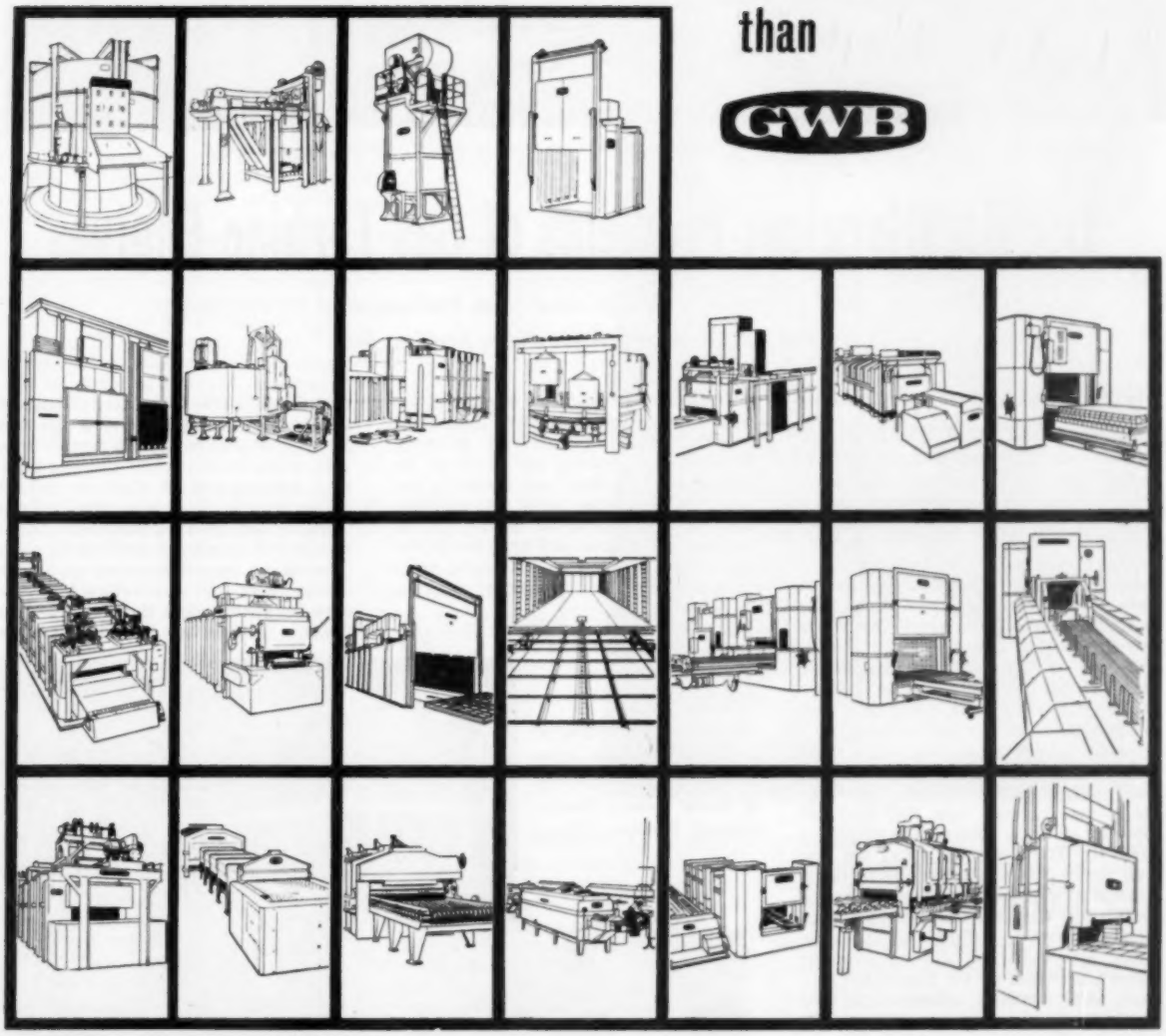

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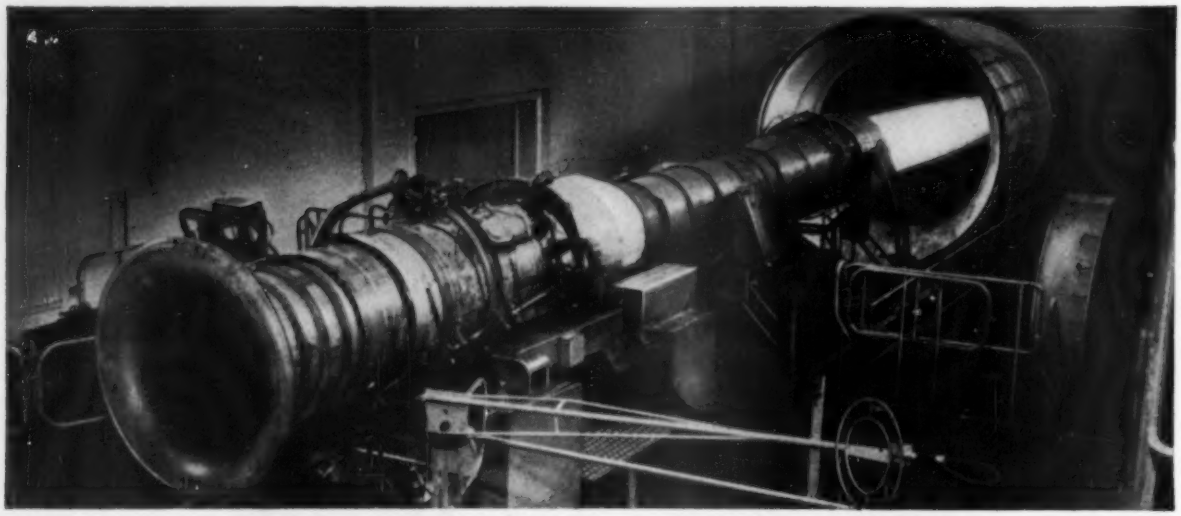

FIG. 1 *An Olympus 201 turbojet engine on test at the Patchway, Bristol, factories of Bristol Siddeley Engines Limited*

The Metallurgical Problems of Gas Turbine Engines

"That gas should be so extensively used is an indication of its versatility and excellence as a precision heating fuel"

Many such problems are encountered by Bristol Siddeley Engines Ltd., a company formed as recently as April 1959 by the merger of Bristol Aero Engines and Armstrong Siddeley Motors, which were the respective aero engine manufacturing companies of the Bristol Aeroplane Company and the Hawker Siddeley Group. The new engine company is one of the largest of its kind in the world and offers an extremely wide range of propulsion units both for manned aircraft and missiles.

There is no doubt that in aero engine manufacture the limitations are almost entirely those of the performance of new alloys and the ability to form and process these alloys satisfactorily. The turbine and rotor blade forge shop at the Patchway Works houses four forging presses varying from 800 to 1,000 tons and six drop hammers from 400 to 2,000 lb. These are fed from ten gas fired muffle furnaces operating through a range of temperatures from as low as 450°C for the low temperature aluminium alloys to 1150°C for the high nickel alloys. In this shop aluminium alloys are heated by air circulation furnaces while Nimonic, stainless steel and titanium alloys are processed in muffle furnaces. The variety of blade lengths varies from ½" to 12" in overall length, and for some of the alloys a reducing atmosphere is required and obtained from cracked ammonia. The number of blades in a typical engine varies from 1,000 to 2,500 and these represent the number of potential points of a failure if one of these blades is incorrectly formed and processed. The whole of the forge shop uses gas for heating the dies as well as the furnaces, and as was pointed out by one of the engineers, the temperature time sequence using heat resisting alloys particularly is very critical. The soaking period must be adequate but it must not exceed a defined period. Gas with its uniform calorific value and its ability to be supplied at a governed pressure facilitates the problems of automatic temperature control on those soaking furnaces.

The precision foundry at Patchway also uses considerable quantities of heat resisting alloys for rotor blades and here gas is used exclusively for mould firing with a time cycle of four to eight hours at a temperature of 1000 to 1050°C. Quite recently two new mould firing furnaces were installed as a result of satisfaction with the former gas fired furnaces. In addition, a gas fired rotary sand dryer operating at 350°C provides hot sand used for melting out the wax from the shells in the lost wax moulding process.

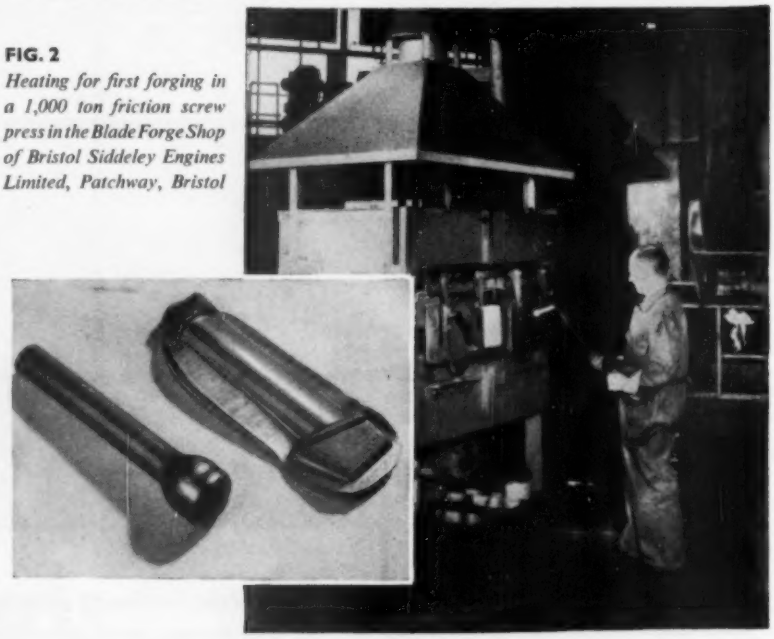

FIG. 2

Heating for first forging in a 1,000 ton friction screw press in the Blade Forge Shop of Bristol Siddeley Engines Limited, Patchway, Bristol

As will be appreciated, there is a certain amount of scale removing necessary, particularly on the components made from heat resisting steels. For this purpose use is made of the sodium hydride process. Basically, this involves preheating the components to drive off moisture and then immersing in a bath of molten caustic soda to which metallic sodium is added. Hydrogen, made by cracking ammonia is led into the mixture of caustic soda and sodium causing the formation of sodium hydride. The action of this material on the surface of the heat resisting steel components is to convert the oxide scale directly into spongy metal without in any way attacking the metal surface. This is advantageous in terms of the maintained precision of the dimensions of the components, and its other advantage is that a 48 hour sequence by the acid methods is replaced by a 4 hour sequence using the sodium hydride process. The temperature is maintained in the bath, which holds seven tons of the molten material, by four manifolds at the corners of the bath, each of which houses five gas burners.

The other essential features of any gas turbine engine are, of course, the jet pipes which again are made from heat resisting alloy. During the fabrication of these tubes up to 30 in. in diameter and from 15 to 20 ft. in length there is a multitudinous number of seam welding operations and it is essential that these welds are stress relieved before the component goes into service. One way of doing this would be to build a large pit furnace which is expensive in terms of capital outlay and occupies permanent valuable factory space. The Company, however, collaborated with the Industrial Engineers of the South Western Gas Board and between them made use of ring burners which had been employed in an entirely different operation in an entirely different industry. The completed jet tubes are held in position over circular gas jets, each of which is in two semi-circular segments. One end of the tube is attached to a revolving holder and the whole tube is capable of revolving round the complete circle of gas flames. These circular burners can be positioned over the various banks of welds in the tube and the stress relieving operation using gas and compressed air is carried out at a temperature of 950°C. According to the different diameters of the jet tubes, so different diameters of circular burners are used. This is a particular example of how the knowledge of the Industrial Gas Engineers of one industry can be directly applied to another.

In the sheet metal shop, as part of the bright annealing process, town gas is burnt and passed through a catalyst, and burnt after which moisture is removed from the combustion products, so providing the necessary neutral atmosphere in the bright annealing furnaces which ensures that the heat resisting steel components emerge after annealing with a bright surface completely free from scale.

Apart from these above mentioned processes, considerable use of town gas is made by Bristol Siddeley Ltd. at their Patchway factory in muffle furnaces, in continuous paint stoving ovens, as oxy-gas profile flame cutters for many heat treatment processes, and for a variety of salt baths, degreasers and metal processing tanks.

In aero engine design and manufacture the metallurgical problems are considerable and ultimate performance depends upon the condition of the final surface of the metal while this, in turn, depends very largely on the manner in which it is heat treated and finished. That gas should be so extensively used is an indication of its versatility and excellence as a precision heating fuel.

Bristol Siddeley Engines Ltd. acknowledge the constant help which they receive from the Industrial Engineers at the South Western Gas Board and, of course, throughout the vast range of processes employing gas in industry, users and potential users of gas can obtain expert technical advice, quite freely, from their Area Gas Board.

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FIG. 3
Sodium hydride plant in the Plating Shop at the Rodney Works of Bristol Siddeley Engines Limited.

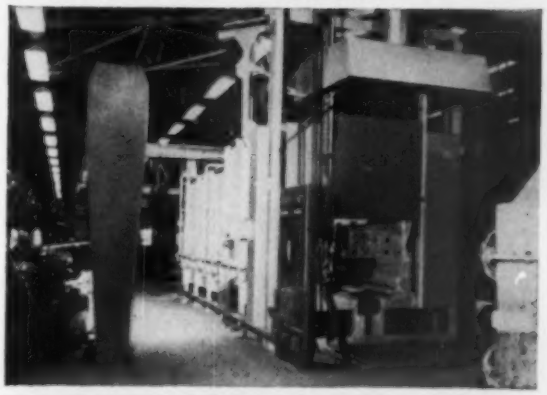

FIG. 4
The mould firing oven in the casting section of the Precision Foundry at Bristol Siddeley.

FIG. 5
Jet pipe weld annealing plant in No. 1 Shop at the Rodney Works of Bristol Siddeley Engines Limited.

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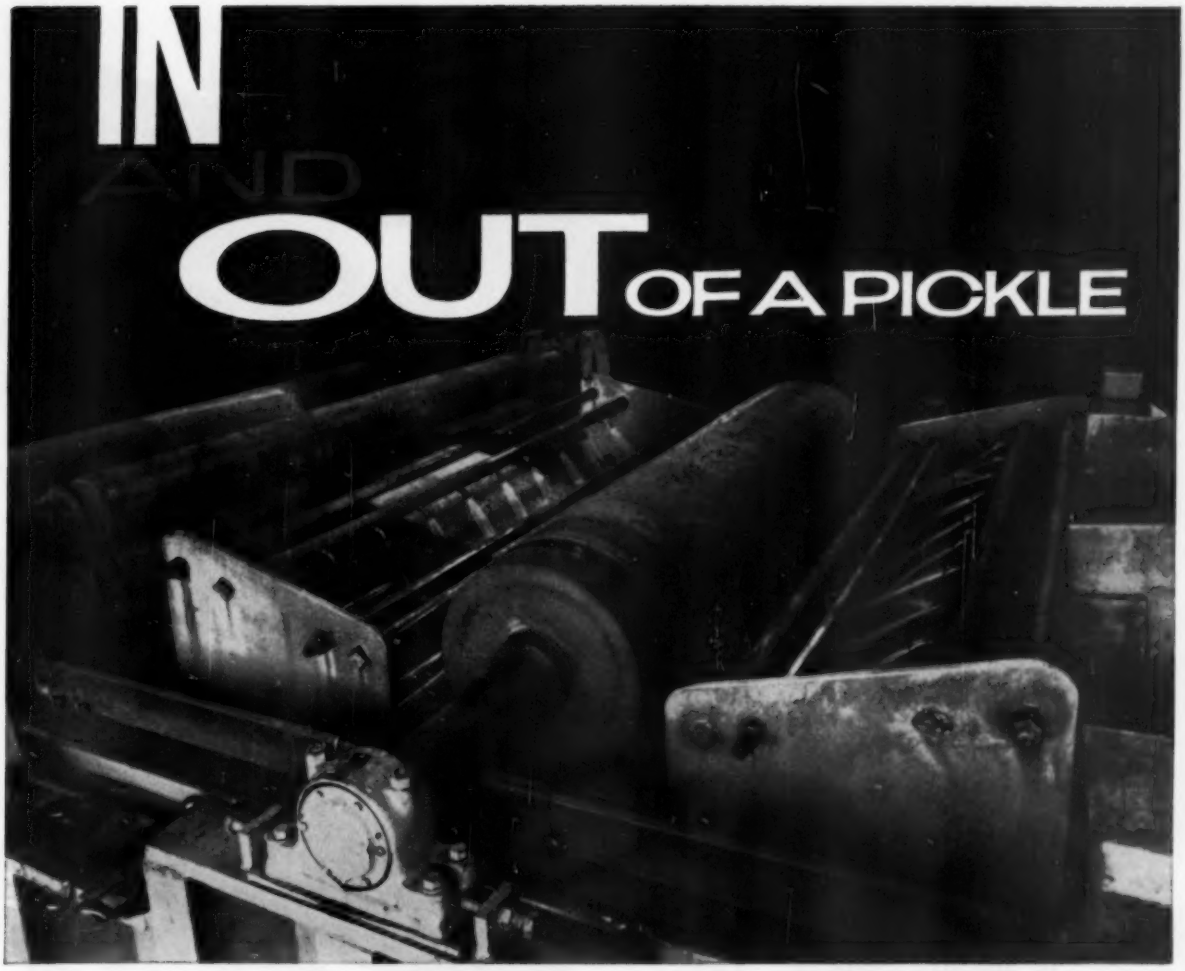

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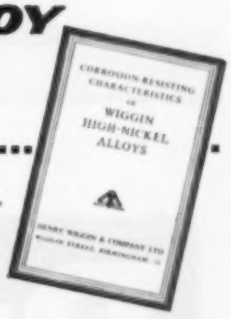

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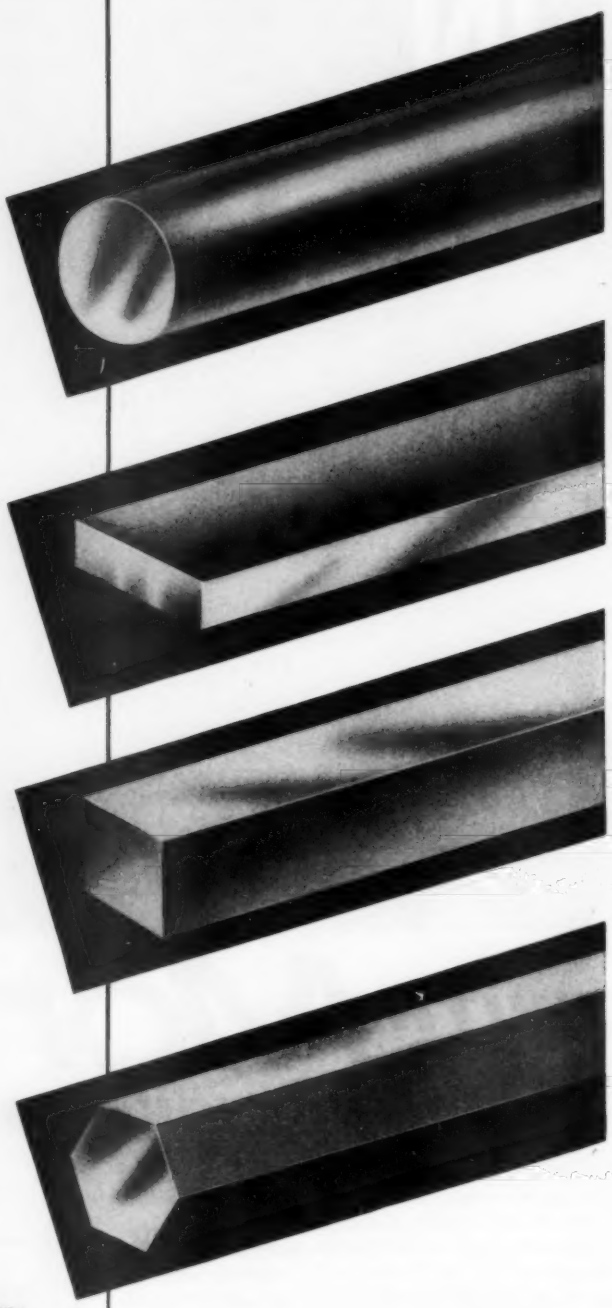

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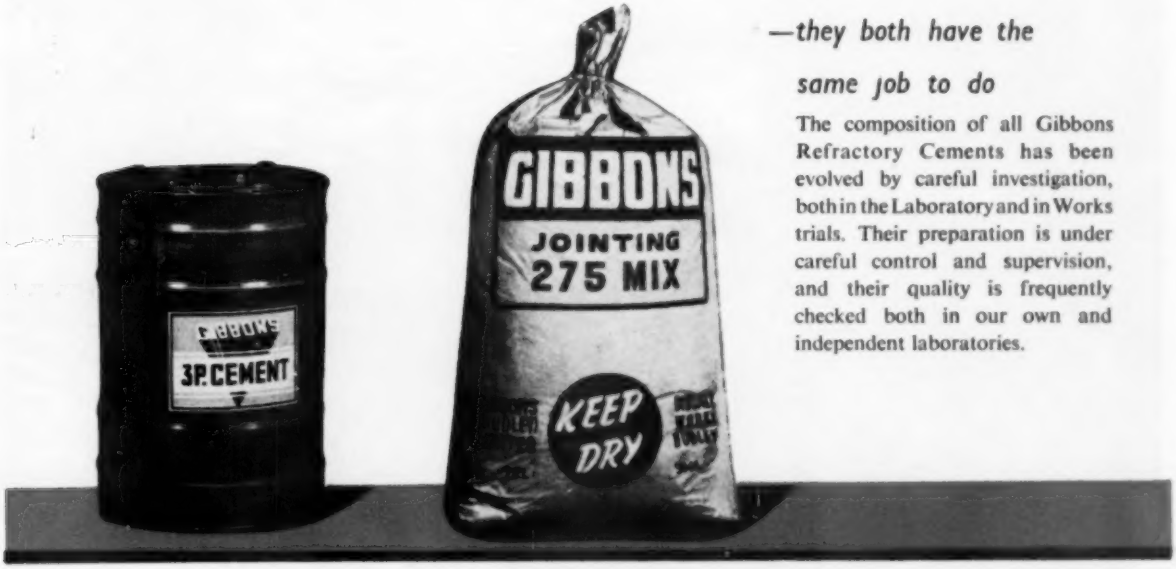

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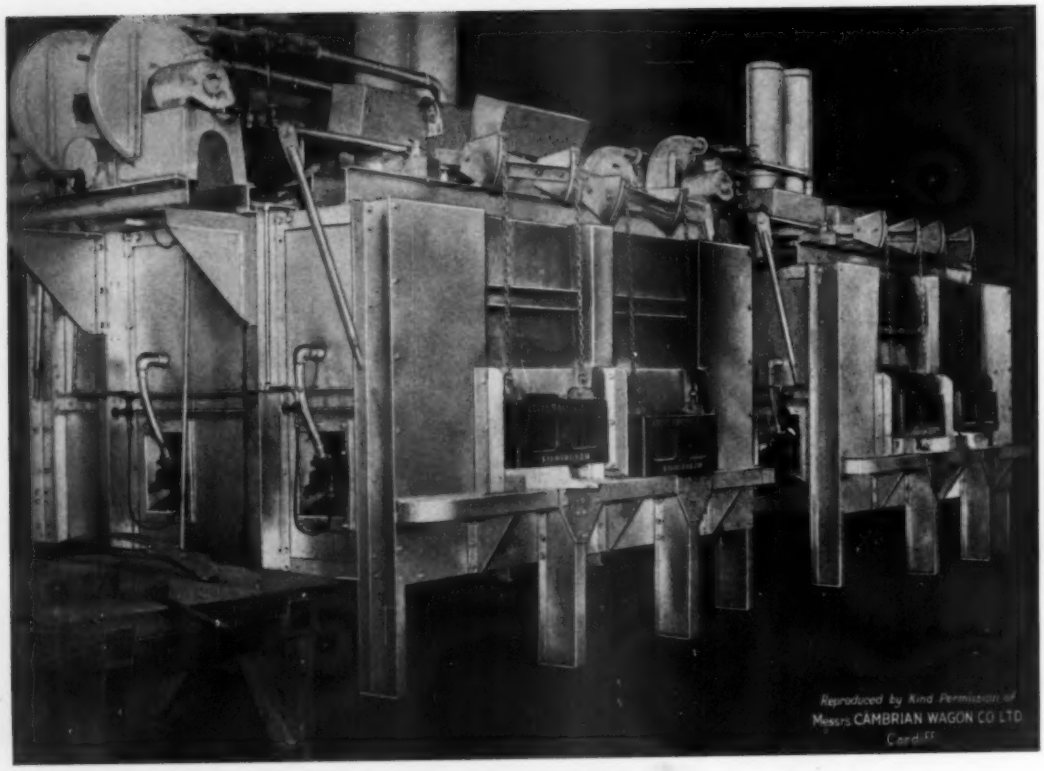

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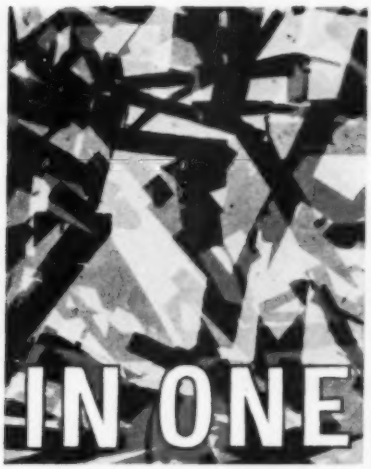

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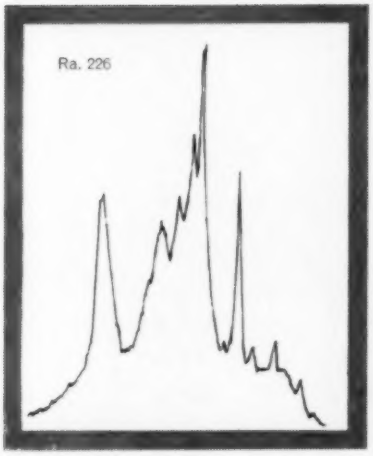

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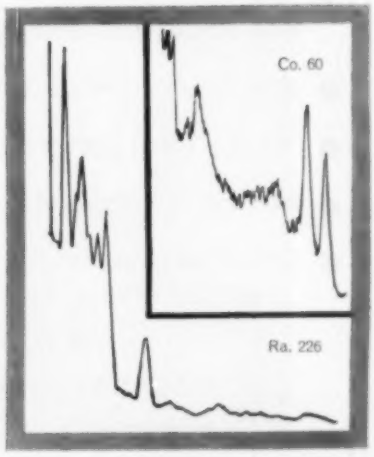

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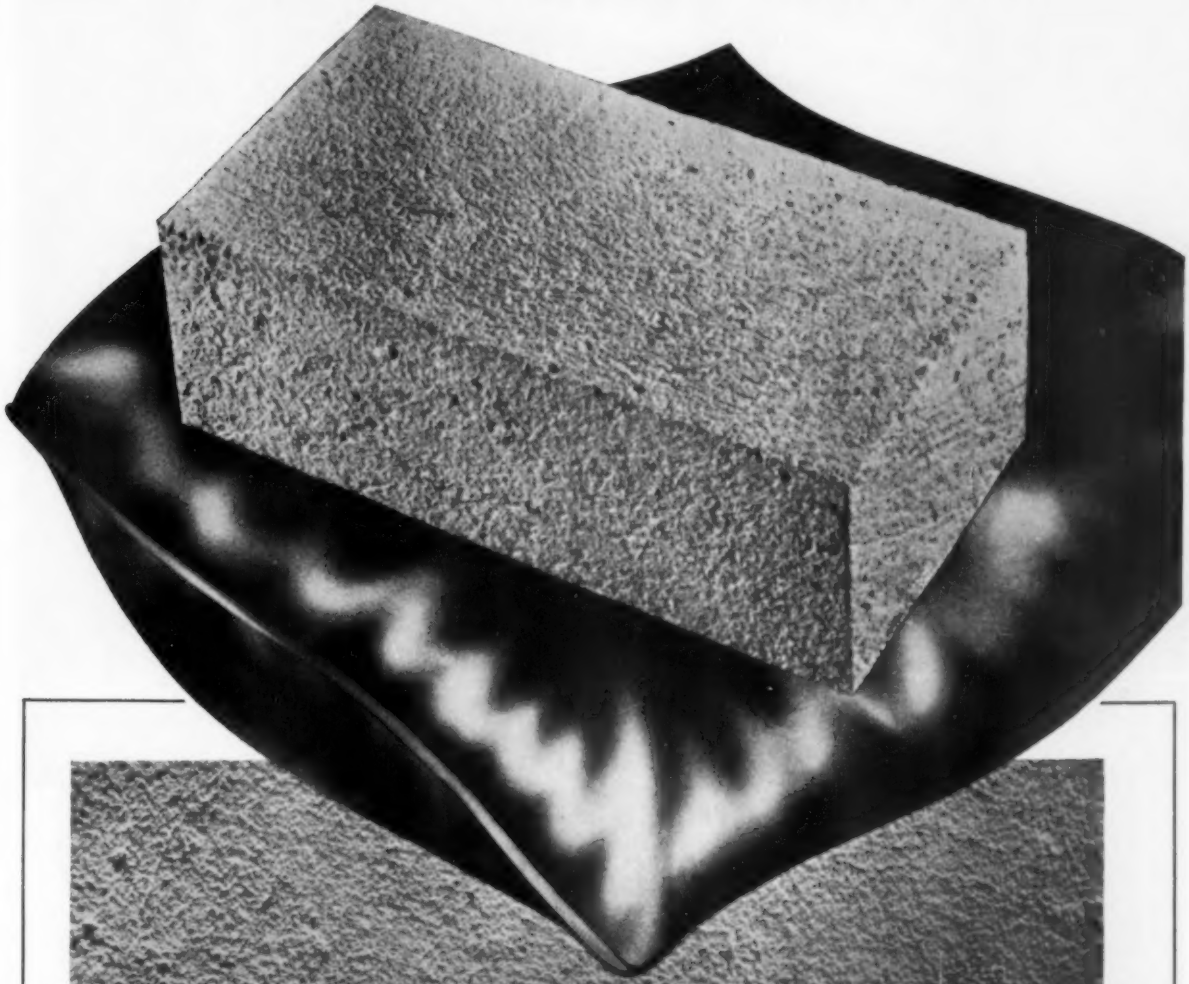

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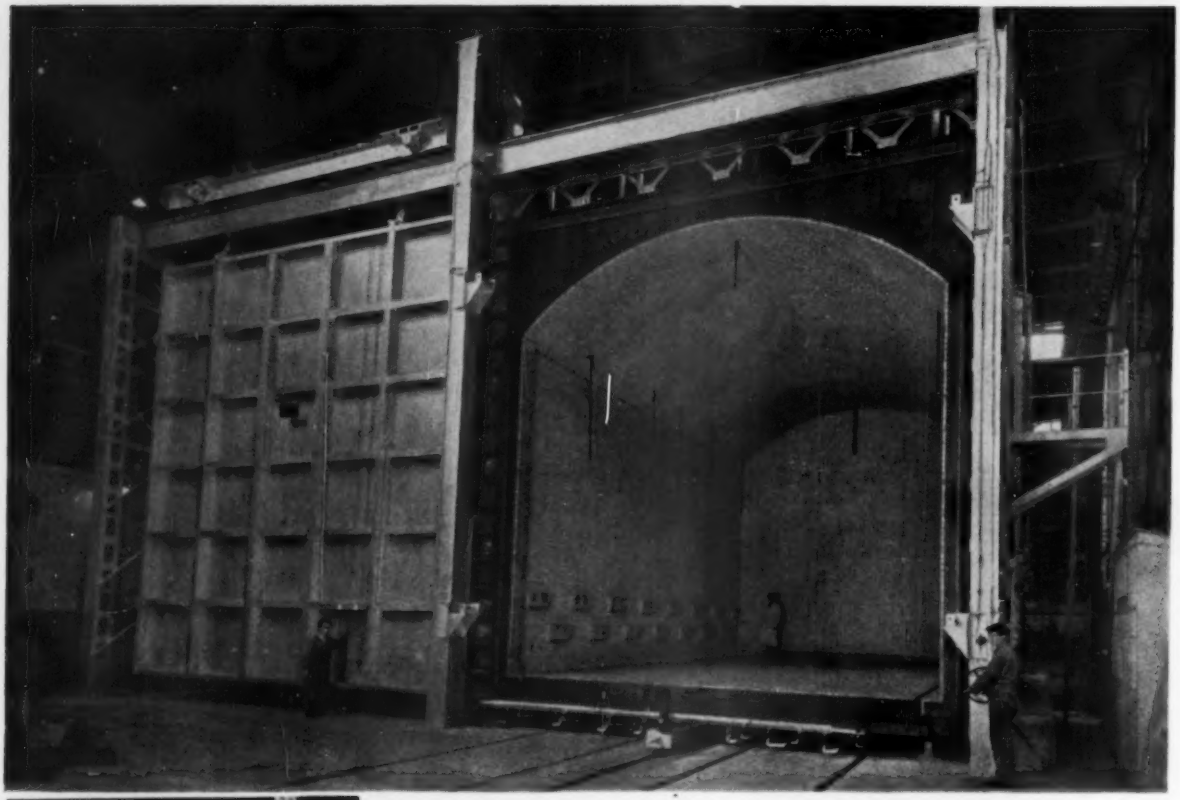

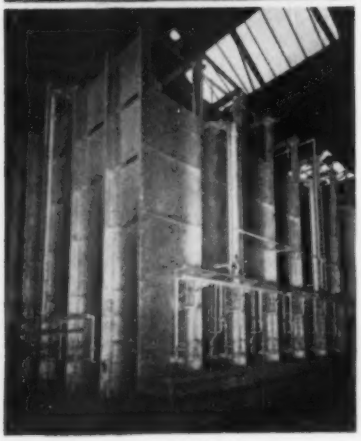

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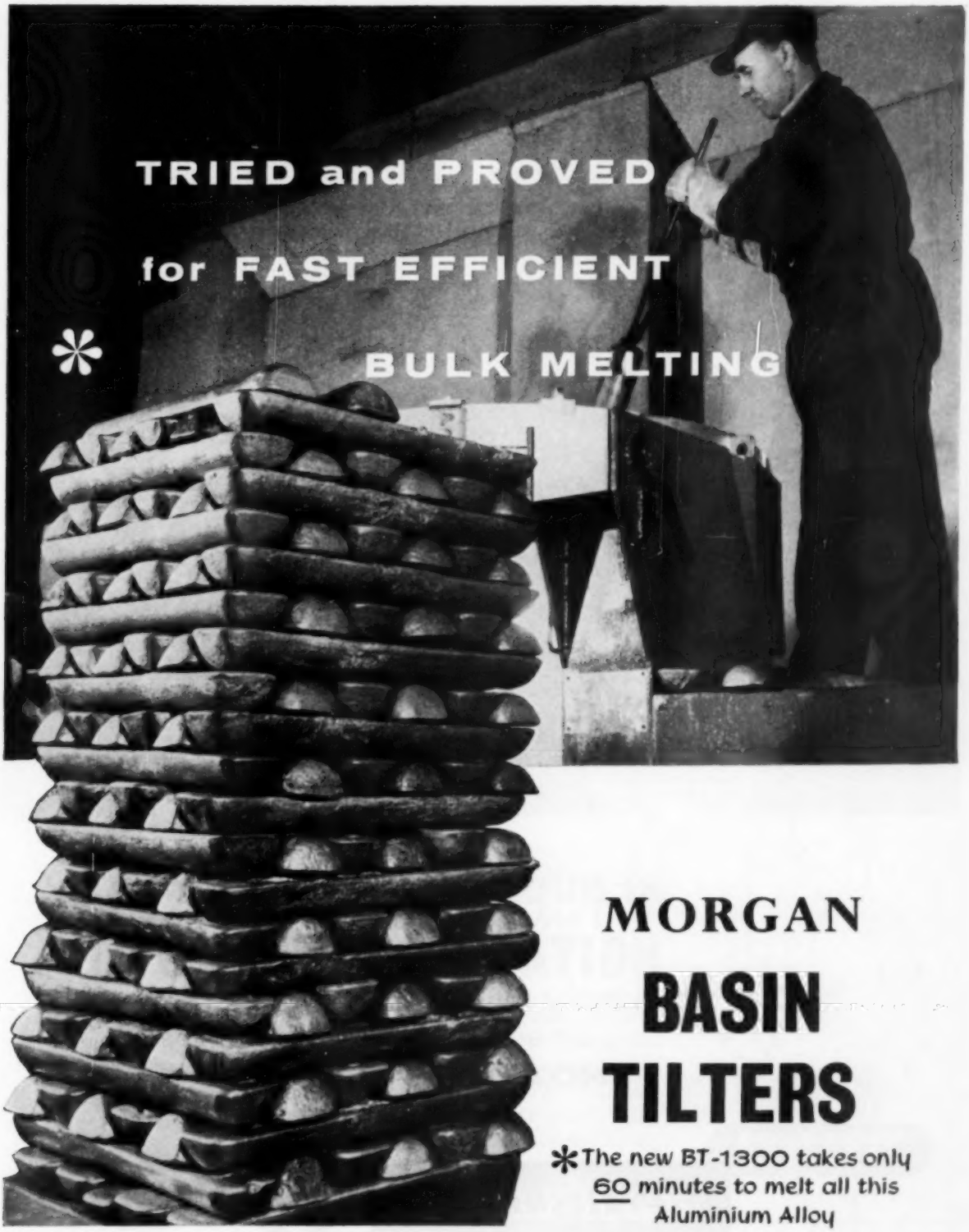

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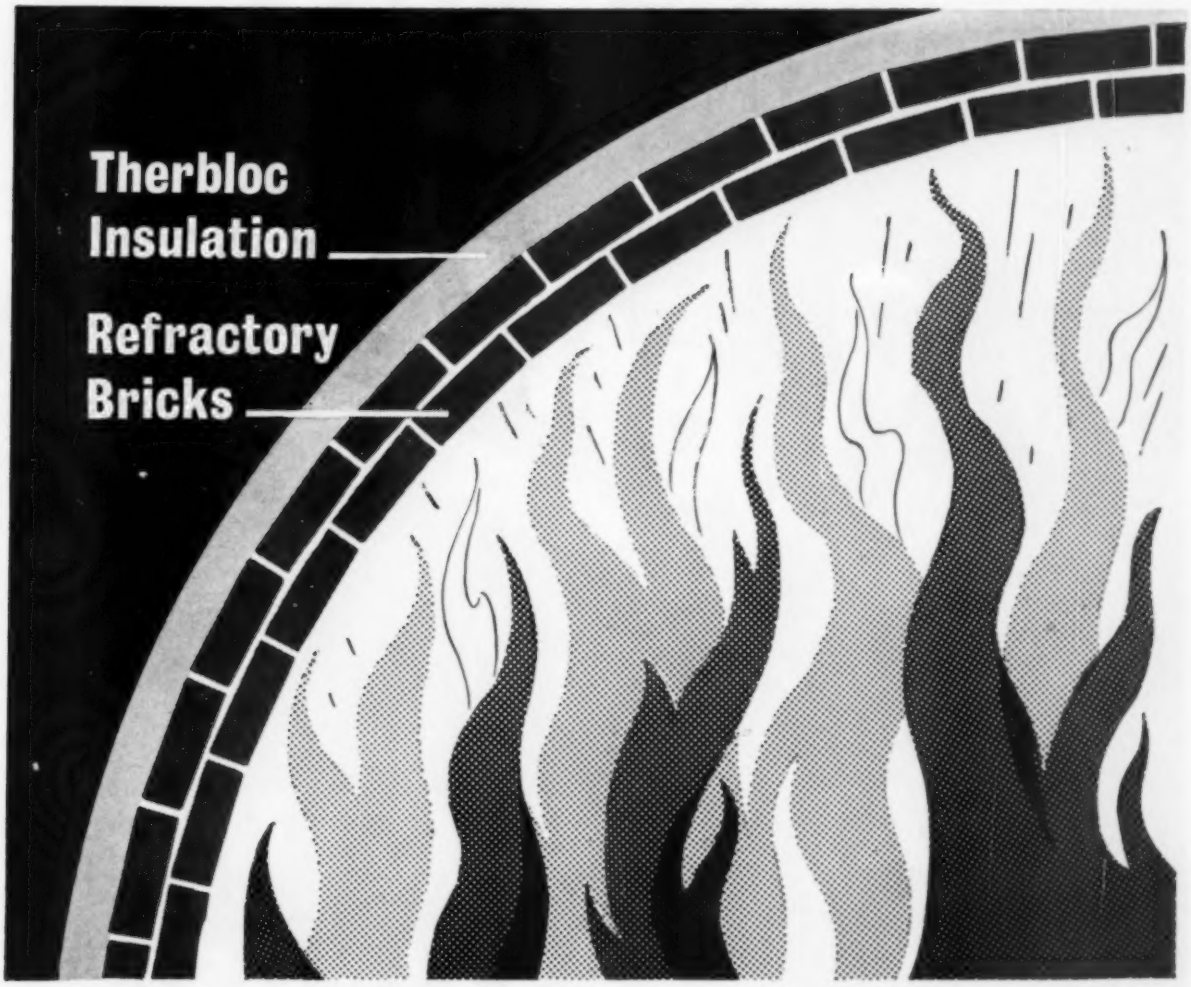

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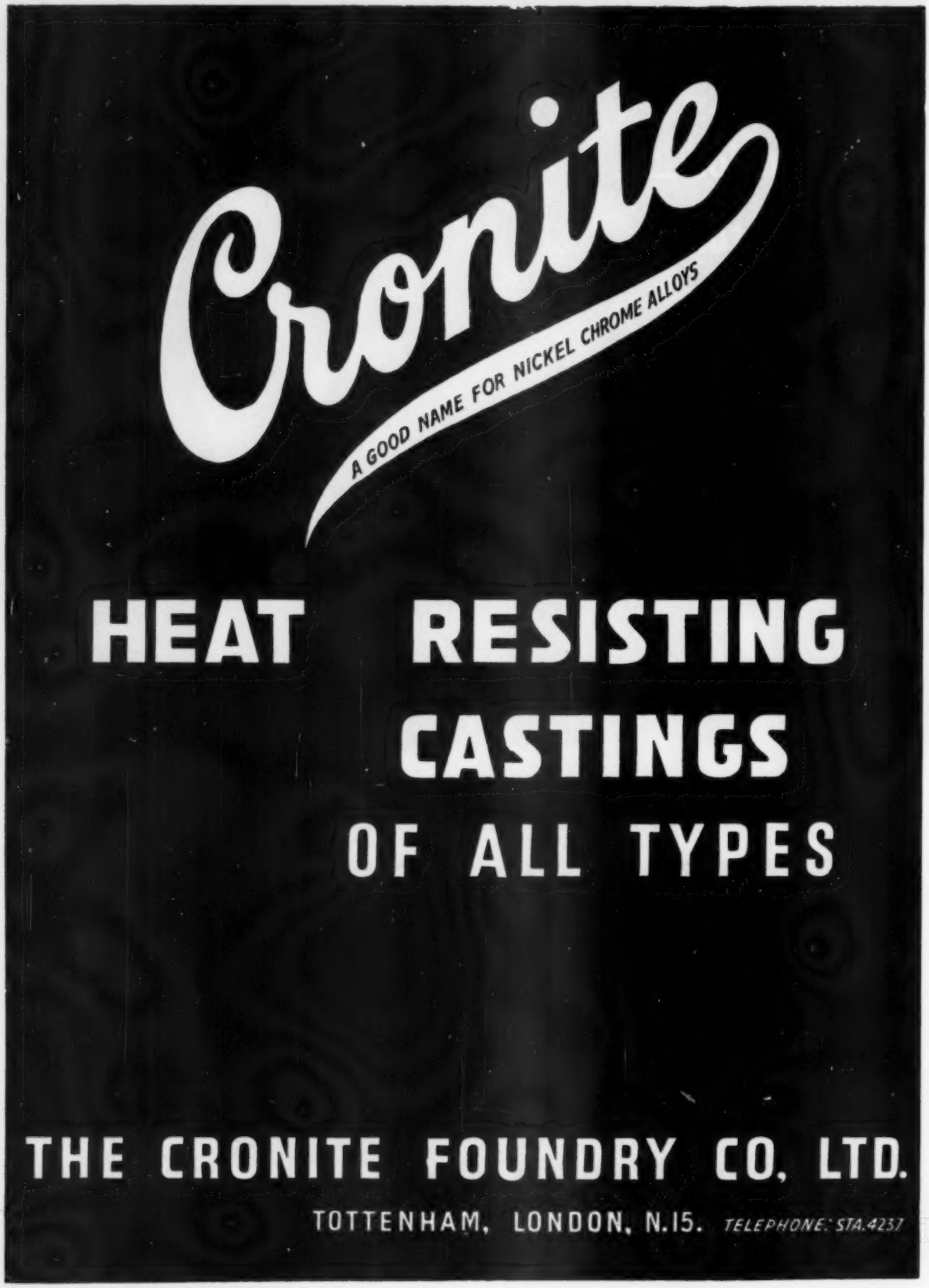
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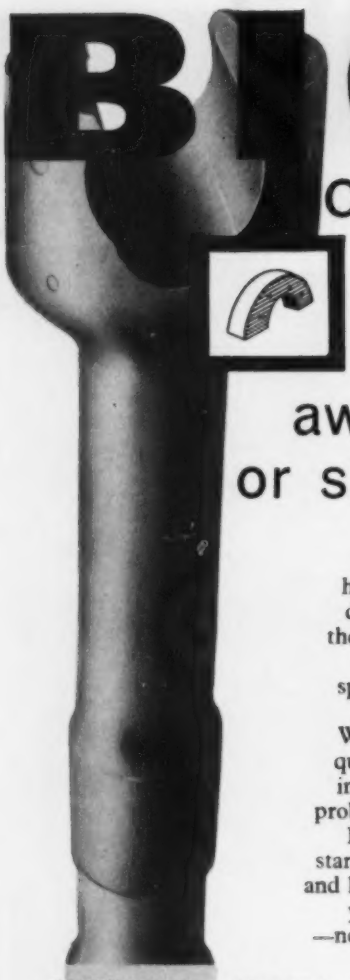

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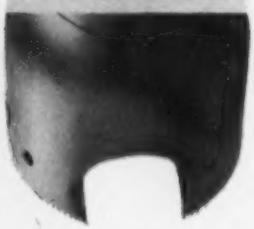

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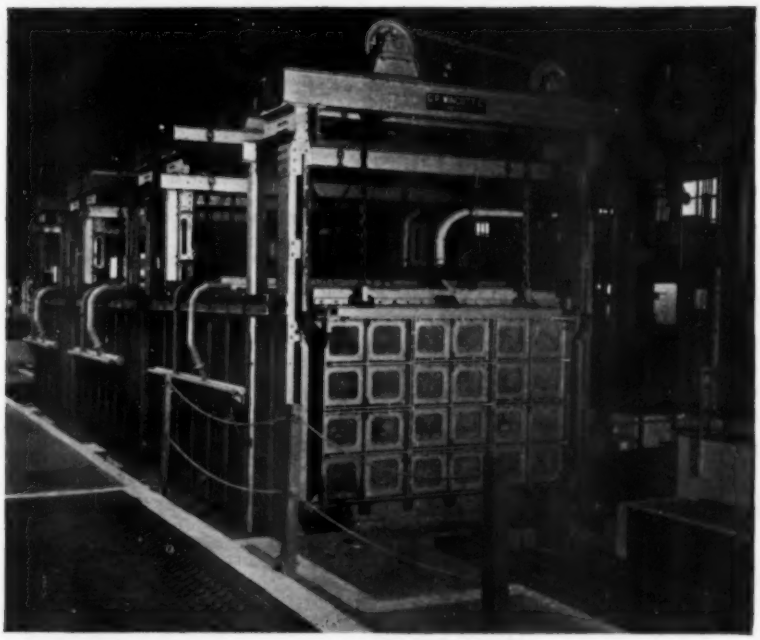

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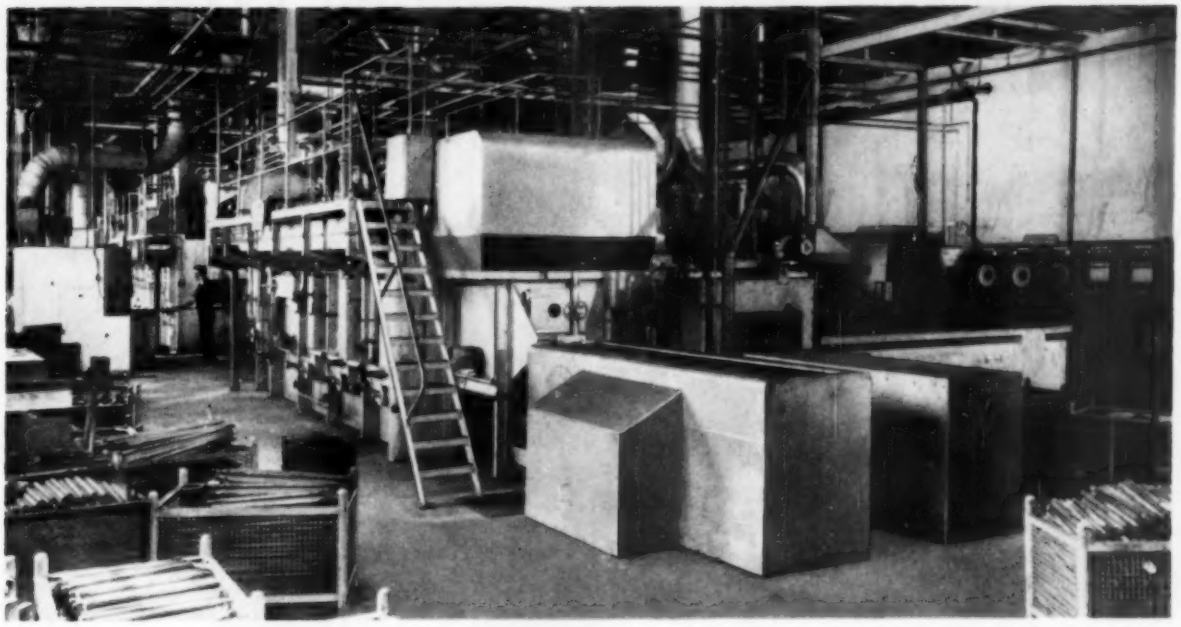

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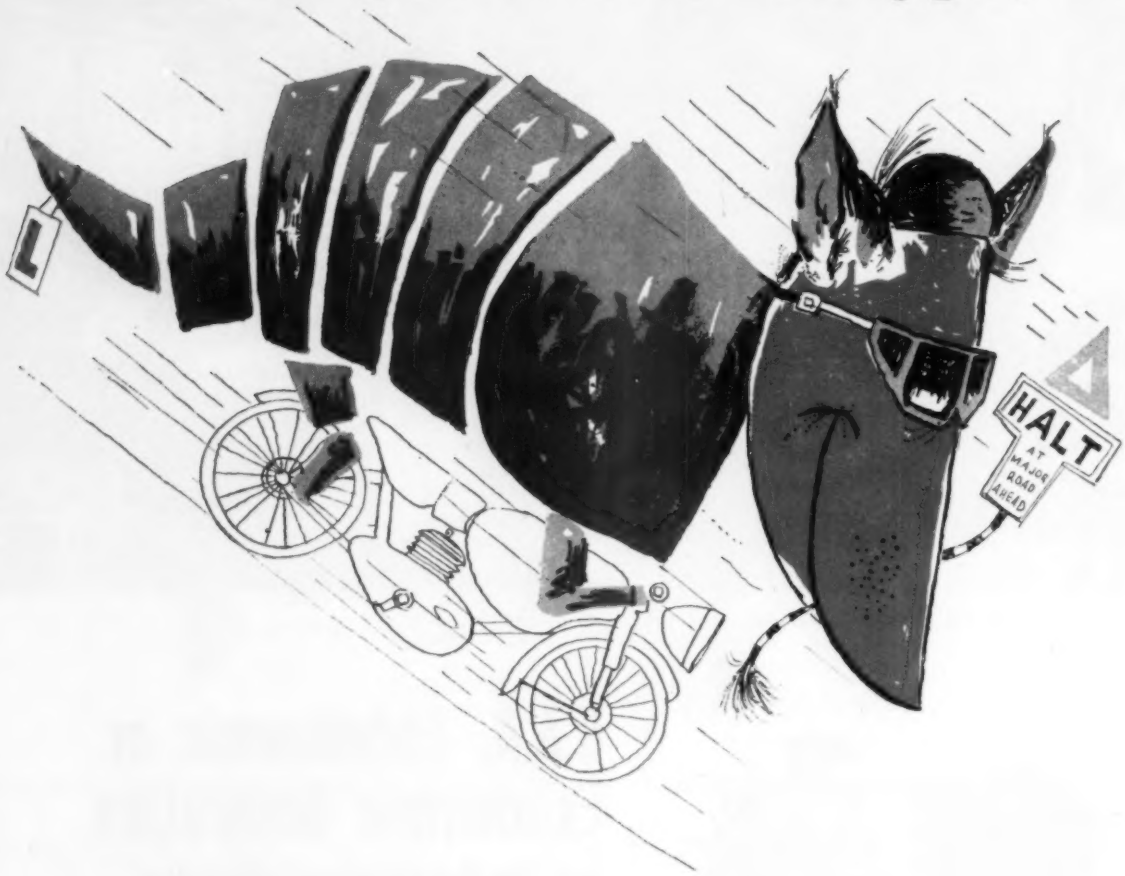

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METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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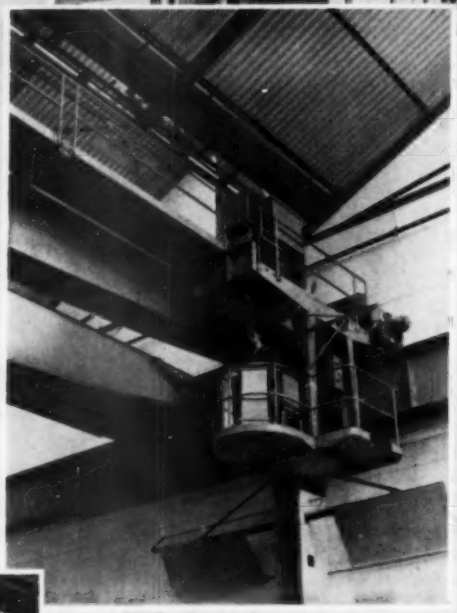

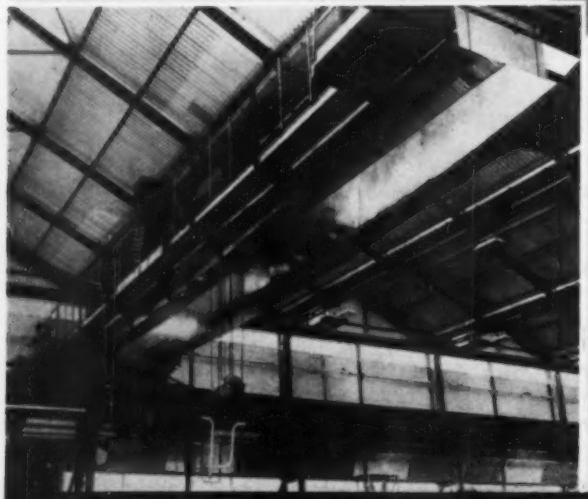

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

OCTOBER, 1961 Vol. LXIV. No. 384

Zinc-Coated Steel for Cars

IT has truly been said that beauty is in the eye of the beholder, for undoubtedly circumstances and personal feelings affect our mental reactions to what we see. Take snow, for example: to see a landscape covered with a layer of virgin snow evokes in most of us a response to its beauty, for snow can make a picture out of very ordinary things, many of which without it might even be considered ugly. Once this first impression on looking out through the bedroom window in the early light of dawn has passed, there set in the secondary reactions based on past experience. The child is full of joyous thoughts at the prospect of sledging and snowballing—the tingling fingers being forgotten or ignored; to their elders come visions of clearing paths and ploughing through the stuff on their way to work.

There is in man a destructive streak—as witness the attraction of the crockery-smashing stalls at the fairground—but in most of us it is held in check, or vandalism would be so prevalent as to make the present scourge seem insignificant. The sight of a snow-covered road brings out the destructive streak in the highways department: word goes out that it must be destroyed, and the armies sally forth armed with salt and sand to carry out their task. True, they have reason on their side, inasmuch as traffic would otherwise be brought to a crawl, if not to a halt, and chaos would ensue.

By the highway department's actions the roads are made much safer for traffic, but not without considerable cost, quite apart from the materials and labour involved, for the road surface appears to be adversely affected, and there is no doubt that the vehicles using it are. The metallurgist—particularly if his motor car is paid for entirely out of his own pocket—contemplates with something akin to horror a journey on salted and sanded roads, knowing full well that he is putting the underbody through an accelerated corrosion and abrasion test. Many attempts have been made to combat this and other types of corrosion by better pretreatment procedures prior to painting, by better paints, and by the use of undersealing compounds. In the United States a further step has been taken by the use of zinc-coated steel, and representatives of the zinc industry have visited the U.S.A. to obtain the most up-to-date information on materials and techniques.

Zinc-coated steel has been used in motor cars for many years, but only in fittings such as fuel tanks, silencers and exhaust pipes, the ventilation system, and head and tail lamp assemblies. Recently the effect of corrosion on the strength as well as on the appearance of motor cars has forced U.S. manufacturers to use more corrosion-resistant materials in critical areas of the main body and underbody assemblies. The two major factors responsible for this trend are the change to unitised body construction in place of the conventional chassis and body assembly, and the increasing use of salt on the roads for de-icing purposes. Of all the commercially feasible protective coatings only zinc coatings have so far provided the required combination of properties with respect to forming, spot welding and finishing.

The marked growth in the use of zinc-coated sheet by the U.S. automobile industry is illustrated by the fact that its demand for this material has risen from 87,000 tons in 1955 to 219,000 tons in 1960, the proportion of hot galvanised material having increased in the same period from 55% to 80%. In addition, it is estimated that some 9,000 tons of zinc dust (for paints) was used by the automobile industry in 1960. A gradual conversion to unitised construction for all vehicles, and an extension of its use to more components will lead to a big increase in the consumption of galvanised sheet by the industry, and it is estimated that some 800,000—1,000,000 tons per annum will be required by 1965.

Considerable interest in this development has been shown in the U.K., and the account of current practice in the U.S.A. which appears in the report of the zinc industry's representatives on their visit to America should prove of considerable assistance to British industry. Issued by the Zinc Development Association, it deals principally with the materials and techniques used in the automobile industry, but an appendix describing some of the special techniques used in the production of hot dip galvanised strip is also included for the guidance of British steel producers.

Two of the main problems presented by the use of galvanised strip are concerned with spot welding and finishing. Initially, strip with a differential coating was required in order to minimise spot welding difficulties, but advances in technique have resulted in a growing demand for a uniformly coated strip possessing a minimised spangle (smooth finish) and a nominal coating weight of 1¼ oz./sq. ft. Details are given of general spot welding practice, stress being laid on the importance of the proper selection and control of welding conditions.

On the matter of surface finish, the first requirement is the production of smoother finishes by reducing the spangle on the sheet, usually achieved by steam jets on both sides of the strip shortly after it emerges from the zinc bath. A further refinement in finish is obtained by giving the product a final skin pass through grit blasted rolls, the sheet undergoing a reduction of ¼–1% in this operation. Normal practice of the steel companies was to supply the sheet or strip with a chromated finish as an anti wet storage stain measure, but because of the alleged difficulty in welding through the chromated surface, all sheet and strip supplied to the motor car industry is oiled only. The use of hot galvanised strip is largely confined to the underbody, where problems of obtaining a high quality paint finish do not arise. Some strip is, however, used for visible parts and in these cases it is desirable to obtain, with the same paints, a

finish comparable with that obtained on uncoated strip. For such cases a single phosphating treatment has been developed which allows a good finish to be obtained on the special grade of hot galvanised strip preferred for exterior panels.

Although hot dip galvanised strip is progressively replacing zinc-rich paints, there will still be some demand for the latter materials. In addition to the spray application of zinc-rich paints to the whole or part of the surface of fabricated sections, there is also interest in the one side coating of strip by roller techniques, but formability remains a problem.

Because of doubts about the suitability of galvanised surfaces as a base for standard external paint finishes, there is still considerable interest in one side coated material, and a number of processes for producing it are being investigated. Development work is also in progress on fast electroplating techniques, with a view to producing electrogalvanised coatings of adequate thickness at a cost comparable to hot dip galvanising.

The authors of the report conclude that although the introduction of hot dip galvanised strip has involved some modification of the techniques for fabrication, assembly and finishing, the changes have been relatively slight, and point out that the results of development work in the automobile industry—particularly with respect to spot welding technique—will be most useful in other fabricating industries.

Meeting Diary

25th October

Institute of Marine Engineers, North Midlands Section. "Heatless Repairs to Fractured or Broken Castings," by N. TINWELL. B.I.S.R.A., Hoyle Street, Sheffield. 7.15 p.m.

Institution of Mechanical Engineers. Presidential Address: "Co-Ordination in Engineering Research and the Conservation of Scientific and Technical Manpower," by SIR KENNETH HAGUE. 1 Birdcage Walk, Westminster, London, S.W.1. 6 p.m.

Manchester Metallurgical Society. "Education in the Metallurgical Field." General Discussion introduced by: L. W. DERRY, PROFESSOR H. O'NEILL, and D. R. O. THOMAS. Manchester Literary and Philosophical Society, George Street, Manchester. 6.30 p.m.

Polarographic Society. "Some Special Problems in the Polarography of Indium and Tellurium," by PROFESSOR DR. M. VON STACKELBERG. School of Pharmacy, 29-39 Brunswick Square, London W.C.1. 2.30 p.m.

26th October

Institute of Metals, Birmingham Local Section. Presidential Address to the Birmingham Metallurgical Society by S. HESLOP. College of Advanced Technology, Gosta Green, Birmingham. 6.30 p.m.

Southampton Metallurgical Society. "Metallurgy of Uranium," by J. J. STOBO. Southampton University. 7.15 p.m.

27th October

Institute of Metal Finishing, Sheffield and North-East Branch. "Recent Developments in Bright Silver Plating." Grand Hotel, Sheffield. 7 p.m.

31st October

Sheffield Metallurgical Association. "Casting in a Vacuum," by L. S. TAYLOR. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

1st November

Manchester Metallurgical Society. "Problems Associated with the Welding of Heavy Sections" by A. F. GIFFORD. Manchester Literary and Philosophical Society, George Street, Manchester. 7.15 p.m. (Joint Meeting with the **Institute of Welding, Manchester and District Branch**).

2nd November

Institute of Metals, London Local Section. "The Design of Strong Materials," by A. H. COTTRELL. Royal School of Mines, London, S.W.7. 7.0 p.m.

Leeds Metallurgical Society. Joint Meeting in Leeds with the Institution of Metallurgists.

7th November

Institute of Metals, Oxford Local Section. "Bearing Materials," by P. G. FORRESTER. Cadena Cafe, Cornmarket Street, Oxford. 7.15 p.m.

Institute of Metals, South Wales Local Section. Discussion on Extrusion. "Hot Extrusion of Non-Ferrous Metals," by PROFESSOR A. R. E. SINGER and "Hot Extrusion of Steel," by R. COX. College of Technology, Swansea. 6.30 p.m. (Joint meeting with **Swansea and District Metallurgical Society**)

Institution of Plant Engineers, London Branch. "Pilot-scale Research Work at the D.S.I.R. Warren Spring Laboratory," by S. H. CLARKE. Royal Society of Arts, John Adam Street, Adelphi, Strand, W.C.2. 7 p.m.

Sheffield Metallurgical Association. "The Analysis of Refractory Materials," by H. BENNETT. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

9th November

East Midlands Metallurgical Society. "Electron Beam Welding," by M. HARPER. Derby and District College of Art. 7.30 p.m.

Institute of Metals, Birmingham Local Section. "The Welding of Metals," by D. R. THORNEYCROFT. College of Advanced Technology, Gosta Green, Birmingham. 6.30 p.m.

Liverpool Metallurgical Society. "Metallurgical Aspects in the Development of Fast Fission Reactors," by PROFESSOR C. R. TOTTLE. Department of Metallurgy, The University of Liverpool, Liverpool 3. 7 p.m.

11th November

Institute of British Foundrymen, Scottish Branch. "Foundry Planning and Production Control," by DAVID MCLEAN. Royal College of Science and Technology, Glasgow. 2.30 p.m.

Institution of Plant Engineers, Edinburgh Branch. "Gas in Industry," by A. MACKECHNIE. 25 Charlotte Square, Edinburgh. 7.30 p.m.

13th November

Institute of Metals, Scottish Local Section. "The Effects of Irradiation on Materials," by H. M. FINNISTON. Institution of Engineers and Shipbuilders, Elmbank Crescent, Glasgow C.2. 6.30 p.m.

14th November

Sheffield Metallurgical Association. "Properties and Fabrication of Some of the Newer Metals (Beryllium, Hafnium, Zirconium, Niobium and Tantalum)," by N. P. INGLIS. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m. (Joint meeting with the **Sheffield Section of the Royal Institute of Chemistry**)

West of England Metallurgical Society. A discussion on "Teaching Metallurgy to Metallurgists and Engineers," by PROFESSOR J. G. BALL and L. W. DERRY. The College of Science and Technology, Ashley Down, Bristol 7. 7 p.m.

15th November

Institution of Plant Engineers, East Midlands Branch. "Coal Utilisation," by DONALD HICKS. Sherwood Room, County Hotel, Theatre Square, Nottingham. 7 p.m.

(continued on page 188)

Strain Hardening of High Purity Metals

By F. R. Larson* and E. B. Kula*

An extensive literature survey has been conducted on the true stress-true strain properties of high-purity metals. The true strain at maximum load was used as an index of the strain hardening of these metals, and empirical relationships between crystal structure, grain size, and the true strain at maximum load were found. The effects of temperature were also systematised according to crystal structure.

THE recent acceptance of true stress-true strain testing techniques has stirred interest in the strain-hardening properties of polycrystalline metals. The study of variables that affect strain hardening has been hampered by the lack of a simple parameter able to describe the complete strain-hardening properties of a metal. The most accurate way of studying strain hardening is by the slope of the true stress-true strain curve plotted on cartesian coordinates. But it is well known that this slope varies with strain and a complete description requires a curve. This procedure is difficult at the best, and in many cases so complicated that analysis and understanding is often impossible. It has been shown by previous investigators[1] that this difficulty can be overcome in part by using the slope at maximum load of the true stress-true strain curve plotted on logarithmic coordinates. Often the logarithmic plot of the true stress-true strain curve is a straight line, but even if it is not, the slope at maximum load is approximately numerically equal to the strain at maximum load. Furthermore, the strain at maximum load is, in general, equal to the maximum uniform strain. This maximum uniform strain, or slope of the true stress-true strain curve at maximum load, has great practical significance, which is the major reason for the choice of this criterion.

Procedure

The results herein reported represent an attempt to study the effect of crystal structure, grain size and temperature upon the true strain at maximum load. Most of the data has been taken from the published literature. In those cases where the true strain at maximum load was not tabulated, the data from the published curves were replotted on log-log coordinates and the slope of this plot was obtained at the point where the slope was equal to the strain. For the cases where the data did not extend up to maximum load, the slope was measured by determining the best straight-line fit to the highest strain values reported. There were several instances where the logarithmic true stress-true strain plots were too curved to use this procedure, and in these cases the data were discarded. It must be emphasised that, as in the case for all mechanical property data, considerable scatter is found.

Effect of Crystal Structure

In order to consider the effect of crystal structure, it is first necessary that the various structures be compared on a common basis, that they are undergoing deformation by the same mechanism, which would be slip. It is well known that the mode of deformation influences the stress-strain curves in single crystals[2] as shown in Fig. 1. The lower curve is for simple slip and the upper curve is for multiple slip. Note the large differences in strain hardening. Furthermore, there is often a region of "easy glide" in the initial portion of a test, when slip is on one system, which is followed by a region of more rapid strain hardening when multiple slip is taking place.[3] From these results it is clear that the number of operative slip systems has some effect on the strain-hardening properties.

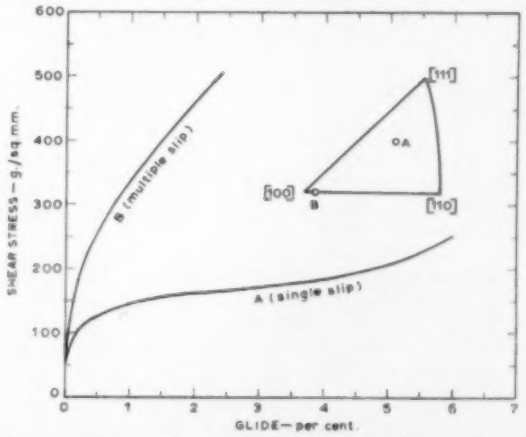


Fig. 1.—Stress-strain curves for pure aluminium crystals deformed by single and multiple slip (after Lücke and Lange[2]).

In Table I are listed the true strains at maximum load for annealed polycrystalline high-purity metals, at a temperature range where this quantity does not change rapidly with temperature. The elements have been separated according to crystal structure. It is striking that elements of the same crystal structure have such similar values, and that the values for the different structures are so different. The major exception is rhenium, and it is known that the deformation of this and other hexagonal metals can be complicated by twinning, in which case it should not be compared on the basis of slip deformation.

It has been shown that the number of slip systems for hexagonal close-packed metals is generally three; for face-centred cubic metals, twelve; and for body-centred cubic, forty-eight. On a simple basis of available slip systems, the b.c.c. metals would expect to strain harden

* Mr. Larson is Chief of the Mechanical Metallurgy Branch and Dr. Kula, Chief of the Mechanical Research Section at Watertown Arsenal, Mass., U.S.A.

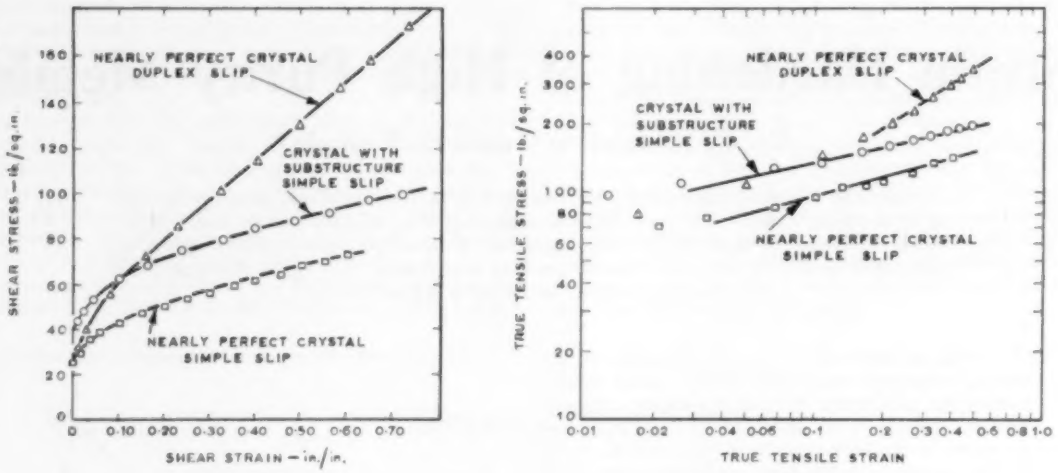


Fig. 2.—Stress-strain curves for zinc single crystals (after Edwards, Washburn and Parker[4]).

more than f.c.c. or h.c.p. metals, which is clearly not the case. It can be further shown that there are three slip directions for h.c.p. metals, four for b.c.c. metals and six for f.c.c. metals. Now, if the different structures are compared on the basis of slip directions (Table II), a relationship is found. For each crystal structure in Table II, the true strain at maximum load is an average value derived from Table I.

The relationship can be formulated as follows:

$$n = k.\,(SD) \qquad (1)$$

where n = true strain at maximum load

SD = number of slip directions

k = a constant, about 0·06

TABLE I.—TRUE STRAIN AT MAXIMUM LOAD.

Crystal Structure	Metal	Range	Mean	Source
Hexagonal close-packed	Titanium	0·12–0·17	0·14	Geil and Carwile[12]
	Titanium	0·13–0·16	0·15	Kula and Larson[14]
	Titanium	0·17–0·19	0·18	DeSisto[15]
	Titanium	0·16	0·16	Rosi and Perkins[16]
	Titanium	0·25	0·25	Jaffee, Ogden, and Maykuth[17]
	Zirconium	0·21	0·21	Keeler[18]
	Zirconium	0·16	0·16	Keeler[19]
	Rhenium	0·33–0·37	0·35	Sims, Craighead, and Jaffee[11]
Body-centred cubic	Iron	0·25	0·25	Raring, Rinebolt, and Harris[20]
	Iron	0·27–0·34	0·32	Smith, Spangler, and Brick[3]
	Iron	0·26–0·28	0·27	Geil and Carwile[21]
	Iron	0·27	0·27	Geil and Carwile[22]
	Iron	0·28	0·28	Low and Garofalo[23]
	Molybdenum	0·22–0·32	0·27	Bechtold[24]
	Molybdenum	0·23–0·25	0·23	Pugh[25]
	Tantalum	0·20–0·28	0·24	Bechtold[27]
	Tungsten	0·26–0·32	0·30	Bechtold and Shewmon[26]
	Vanadium	0·20	0·20	Nash, Ogden, Durtshi, and Campbell[28]
Face-centred cubic	Aluminium	0·27–0·38	0·33	Sherby, Anderson, and Dorn[29]
	Aluminium	0·23–0·29	0·25	Carreker and Hibbard[9]
	Copper	0·58	0·58	French and Hibbard[30]
	Copper	0·30	0·30	Jenkins and Digges[31]
	Copper	0·42–0·48	0·45	Carreker and Hibbard[32]
	Copper	0·33	0·33	Jenkins and Digges[33]
	Nickel	0·34–0·37	0·35	Jenkins and Digges[34]
	Silver	0·45–0·52	0·50	Carreker[35]
	70 Ni–30 Cu	0·38	0·38	MacGregor[36]
	70 Ni–30 Cu	0·30–0·34	0·32	Jenkins, Digges, and Johnson[37]
	70 Cu–30 Zn	0·34–0·44	0·39	Sinclair and Craig[7]

This result could be tested if the number of slip directions and planes could be varied at will in a single metal, and the strain-hardening properties measured. Ideally, this should be carried out on single crystals. Fig. 2*a* shows results obtained by Edwards, Washburn and Parker[4] on single crystals of zinc in pure shear. Three curves are shown, the lower one for the case of simple slip in a nearly perfect crystal, the middle one for simple slip in a crystal showing a substructure, and the upper one for a nearly perfect crystal again, but so oriented that duplex slip (slip in two directions on one plane) is occurring. The shear data have been converted to tensile stress-strain data by assuming a critical shear stress criterion for slip ($\tau = \frac{\sigma}{2}$; $\gamma = \frac{3}{2}\epsilon$). This replotted data, on log-log coordinates, is shown in Fig. 2*b*. The results show that strain hardening for duplex slip as measured by the slope of the log-log plot is approximately double the value for simple slip, as would be predicted by equation (1).

Effect of Grain Size

Unfortunately, systematic studies of the effect of grain size on strain hardening are not extensive. Fig. 3, reproduced from the work of Holloman,[5] shows true stress-strain curves for 70-30 brass of various grain sizes. For each grain size, two straight lines can be drawn through the data. The initial portion of each curve, with a low slope, is thought to be the region of "easy glide"[6] referred to in the previous section. In the range of strain encompassing the maximum load points, the slopes of the curves (true strains at maximum loads) are found to increase with increasing grain size. Other work on brass has confirmed these findings.[7]

Results for titanium[8] show a similar variation of true strain at maximum load with grain size. The results for titanium and brass, as well as some results for aluminium,

TABLE II.

Crystal Structure	True Strain at Maximum Load	Number of Slip Directions	Number of Slip Systems
h.c.p.	0·18	3	3
b.c.c.	0·26	4	48
f.c.c.	0·38	6	12

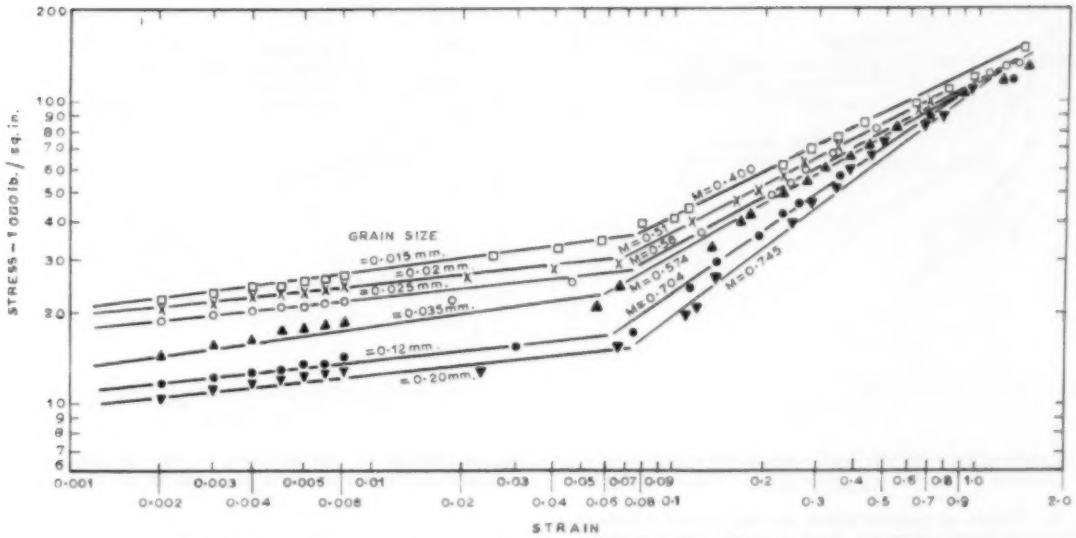


Fig. 3.—Logarithmic stress-strain curves for brass of various grain sizes (after Hollomon[5]).

have been plotted in Fig. 4. In order to facilitate a comparison between the metals of different crystal structure, the true strain at maximum load per slip direction has been plotted versus the grain size on log-log coordinates. With the exception of the data for aluminium, the results fall together in a band. Carreker and Hibbard,[9] who studied the effect of grain size on the plastic properties of aluminium, stated that there was no effect of grain size on the strain hardening. It is thought that it is the subgrain size, rather than the grain size, which controls strain hardening in aluminium.[10] This view is consistent with the data of reference[9] and with the results plotted in Fig. 4, since the true strain at maximum load indicates a grain size much finer than the microscopically observed grain size.

The results mentioned above represent substantially all the true stress-strain data available, where the effect of grain size was systematically studied. More data can be obtained on other metals, however, since in cases where materials of one grain size were studied, the grain size is usually stated. These data are also shown in Fig. 4. Although they considerably increase the scatter, the same trend is exhibited. Again, the variation is independent of crystal structure if the number of slip directions is taken into account. The scatter can at least partially be explained by the fact that impurities are present in many of the metals. Also, it must be remembered that in selecting these data, complete control of the temperature variable was not exercised, since much of the data represents results obtained at room temperature, rather than at some constant fraction of the melting point.

Of special interest in Fig. 4 are the results for zinc,

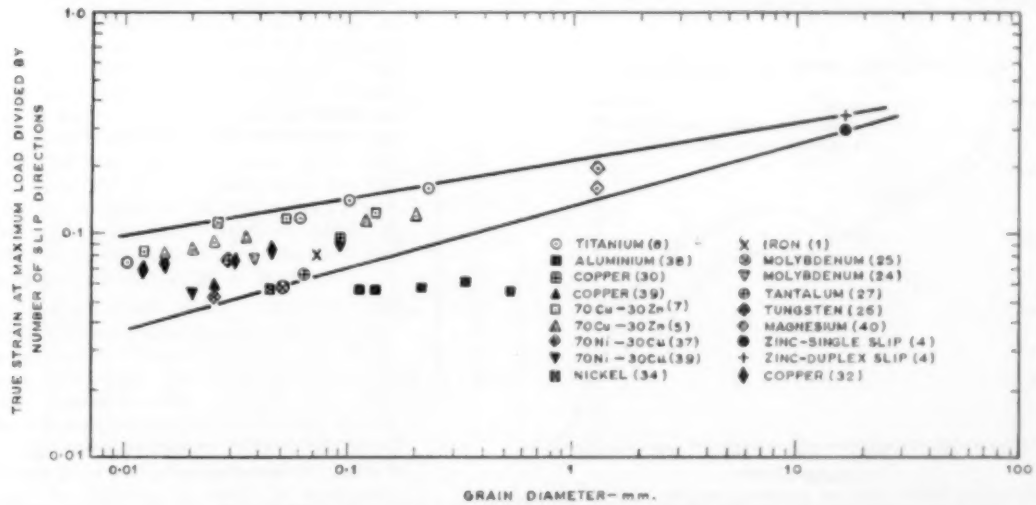


Fig. 4.—Effect of grain size on the true strain at maximum load.

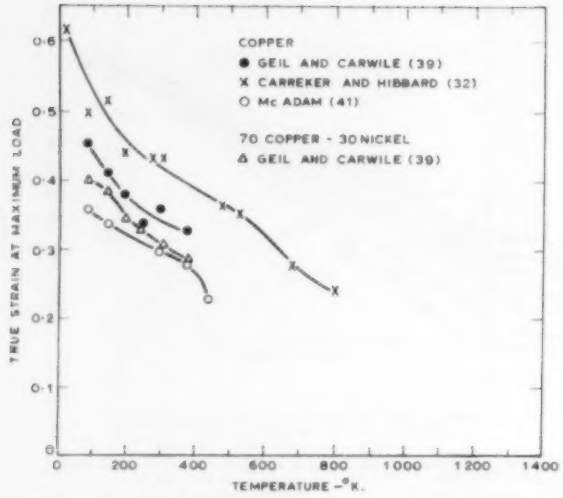

COPPER
● GEIL AND CARWILE (39)
X CARREKER AND HIBBARD (32)
○ Mc ADAM (41)
70 COPPER - 30 NICKEL
△ GEIL AND CARWILE (39)
TRUE STRAIN AT MAXIMUM LOAD
TEMPERATURE - °K.

Fig. 5.—Effect of temperature on the strain hardening characteristics of some face-centred cubic metals.

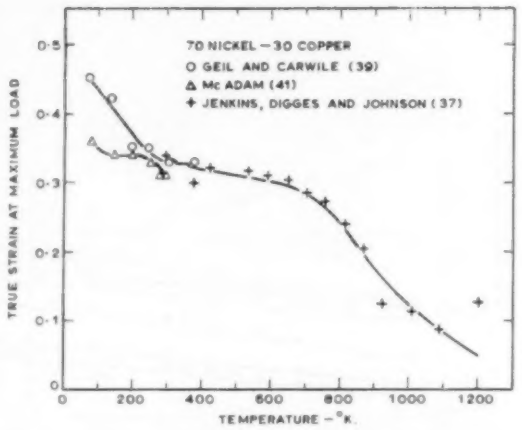

70 NICKEL — 30 COPPER
○ GEIL AND CARWILE (39)
△ Mc ADAM (41)
+ JENKINS, DIGGES AND JOHNSON (37)
TRUE STRAIN AT MAXIMUM LOAD
TEMPERATURE - °K.

Fig. 6.—Effect of temperature on the strain hardening characteristics of face-centred cubic 70-30 nickel-copper alloy.

obtained from shear tests on single crystals,[4] and which are reproduced in Fig. 2. The two points represent single and duplex slip–slip in one and two directions on the same plane. The grain size is the crystal diameter, of course. Even these data fall on an extrapolation of the data for polycrystalline materials. This lends further support to the significance of grain size in controlling strain hardening.

Effect of Temperature

It is generally recognised that most mechanical properties are functions of temperature, and this is especially so if the mode of deformation changes with temperature. Therefore, the variation of true strain at maximum load with temperature should be studied.

Figs. 5–8 show the variation with temperature of true strain at maximum load for some face-centred cubic metals and also for some alloys. There is considerable scatter between the results of different investigators at low temperatures, and this scatter would probably extend to higher temperatures if more extensive testing at elevated temperatures had been carried out. In spite of the scatter, however, definite trends are evident. The true strain at maximum load decreases from a value of over 0·4 at the lowest temperatures to about 0·35 in the vicinity of room temperature, decreases rather slowly with rising temperature at intermediate temperatures, and then decreases rapidly again at high temperatures.

Results for hexagonal close-packed metals (Fig. 9) are more limited. The data for zirconium show little variation with temperature up to 650° K., after which the true strain at maximum load decreases rapidly with increasing temperature. For titanium the results are similar, except that at the lowest temperatures there is a large increase in the true strain at maximum load.

This rapid increase in true strain at maximum load for titanium can be attributed to the occurrence of deformation twinning, which is known to take place at low temperatures. Perhaps if testing of zirconium had been carried out at temperatures approaching absolute

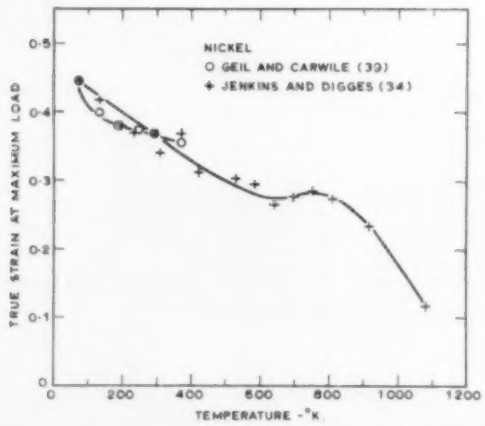


Fig. 7.—Effect of temperature on the strain hardening characteristics of face-centred cubic nickel.

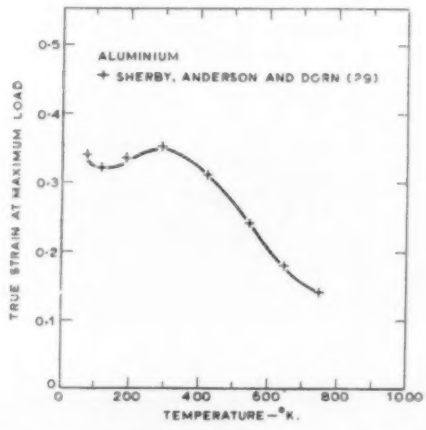


Fig. 8.—Effect of temperature on the strain hardening characteristics of face-centred cubic aluminium.

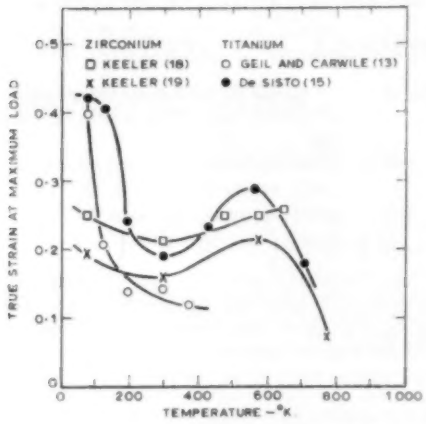


Fig. 9.—Effect of temperature on the strain hardening characteristics of two hexagonal close-packed metals.

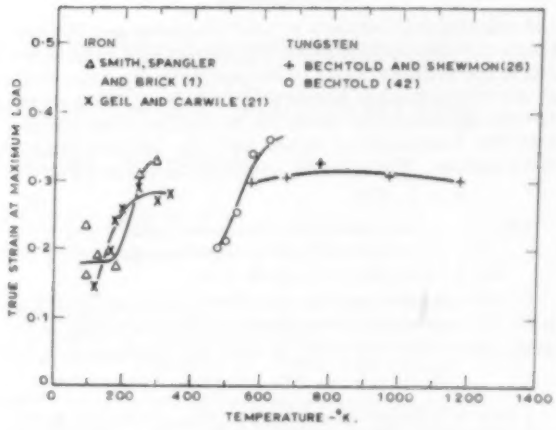


Fig. 10.—Effect of temperature on the strain hardening characteristics of two body-centred cubic metals.

zero, deformation twinning would have occurred here also. Rhenium is reported to have a true strain at maximum load of about 0·35 at room temperature.[11] Since rhenium too is known to twin, it may be possible that twinning is causing the rather high value of true strain at maximum load.

Body-centred cubic metals present an entirely different picture (Figs. 10–12). For these metals there is a maximum in the true strain at maximum load at intermediate temperatures. With both increasing and decreasing temperatures the true strain at maximum load decreases. At the elevated temperatures, the decrease is undoubtedly caused by annealing taking place during the test, as was the case for face-centred cubic and hexagonal close-packed metals.

The decrease in true strain at maximum load for the body-centred cubic metals at low temperatures is a behaviour not exhibited by metals of other crystal structures. In this same temperature range, the yield strength of body-centred cubic metals increases rapidly, and brittleness is prevalent. It must be pointed out, however, that these low values of strain at maximum load are not caused by premature failure, i.e., fracture before maximum load. In each case, the strain at maximum load was exceeded and necking had started prior to failure.

In titanium, there is an increase in yield strength with decreasing temperatures, which is accompanied by an increase in true strain at maximum load. In body-centred cubic metals, however, the increase in yield strength is accompanied by a decrease in true strain at maximum load. Clearly, it is not the increase in yield strength *per se* which is causing the decrease in strain at maximum load.

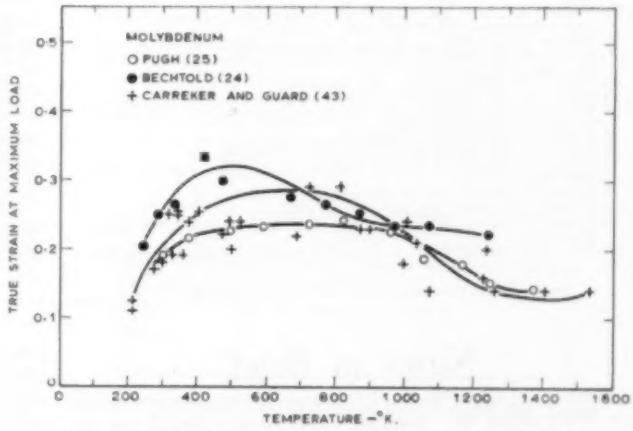


Fig. 11.—Effect of temperature on the strain hardening characteristics of body-centred cubic molybdenum.

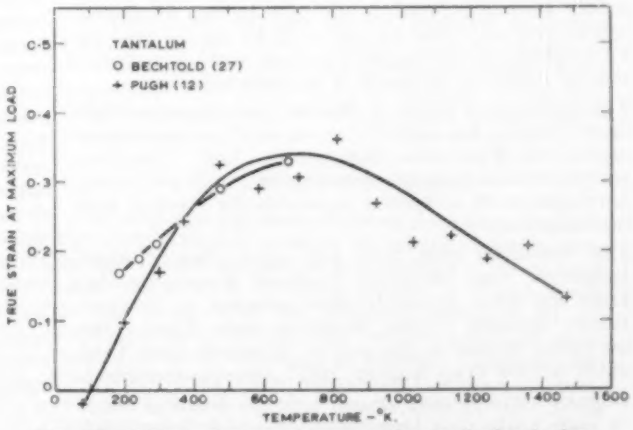


Fig. 12.—Effect of temperature on the strain hardening characteristics of body-centred cubic tantalum.

Conclusions

A relationship between crystal structure and the true strain at maximum load has been shown. In cases where slip is the primary mode of deformation, the true strain at maximum load is proportional to the number of slip directions, which are three for hexagonal close-packed, four for body-centred cubic and six for face-centred cubic metals. The data fit an equation of the form :

$$n = k\,(SD) \qquad (1)$$

where n = true strain at maximum load
SD = number of active slip directions
and k = a constant, about 0·06

Grain size influences the true strain at maximum load with the true strain at maximum load increasing as the grain size. The net result is that the constant k in the previous equation is changed as the following equation defines :

$$k = K\,(GS)^s \qquad (2)$$

where k = the proportionality constant between slip directions and true strain at maximum load
K = a constant (the intercept at a grain size of 1 mm. equal to about 0·18)
GS = grain size in millimeters
S = slope of the log-log plot (about 0·18)

The true strain at maximum load is also a function of temperature and, although the temperature variation is similar for metals of the same crystal structure, it is different for metals having different crystal structure.

BIBLIOGRAPHY

1 Smith, R. L., Spangler, G., and Brick, R. M., *Trans. A.S.M.*, 1954, **46**, 973.
2 Lücke, K., and Lange, H., reported in A. H. Cottrell, " Dislocations and Plastic Flow in Crystals," Oxford, 1953, p. 163.
3 Maddin, R., Mathewson, C. H., and Hibbard, Jnr., W. R., *Trans. A.I.M.E.*, 1948, **175**, 86.
4 Edwards, E. H., Washburn, J., and Parker, E. R., *Trans. A.I.M.E.*, 1953, **197**, 1,525.
5 Holloman, J. H., *Trans. A.I.M.E.*, 1945, **162**, 268.
6 Cracknell, A., and Petch, N. J., *Acta Metallurgica*, 1955, **3**, 186.
7 Sinclair, G. M., and Craig, W. J., *Trans. A.S.M.*, 1952, **44**, 929.
8 Holden, F. C., Ogden, H. R., and Jaffee, R. I., *Trans. A.I.M.E.*, 1953, **197**, 238.
9 Carreker, Jnr., R. P., and Hibbard, Jnr., W. R., General Electric Research Laboratory Report No. 55–RL–1342, July 1955.
10 Fullman, R. L., *Journal of Applied Physics*, 1950, **21**, 1,069.
11 Sims, C. T., Craighead, C. M., and Jaffee, R. I., *Trans. A.I.M.E.*, 1955, **203**, 168.
12 Pugh, J. W., *Trans. A.S.M.*, 1956, **48**, 677.
13 Geil, G. W., and Carwile, N. L., *Journal of Research (N.B.S.)*, 1955, **54**, 91.
14 Kula, E. B., and Larson, F. R., Watertown Arsenal Laboratories Report No. 401/241, September 1955.
15 DeSisto, T. S., Watertown Arsenal Laboratories Report No. 401/281.
16 Rosi, F. D., and Perkins, F. C., *Trans. A.S.M.*, 1953, **45**, 972.
17 Jaffee, R. I., Ogden, H. R., and Maykuth, D. J., *Trans. A.I.M.E.*, 1950, **188**, 1,261.
18 Keeler, J. H., *Trans. A.S.M.*, 1955, **47**, 157.
19 Keeler, J. H., *Trans. A.S.M.*, 1956, **48**, 825.
20 Raring, R., Rinebolt, J. A., and Harris, Jnr., W. J., *Trans. A.I.M.E.*, 1951, **191**, 395.
21 Geil, G. W., and Carwile, N. L., *Journal of Research (N.B.S.)*, 1950, **45**, 129.
22 Geil, G. W., and Carwile, N. L., *Journal of Research (N.B.S.)*, 1952, **48**, 399.
23 Low, Jnr., J. R., and Garofalo, F., Proc. Soc. Exp. Stress Analysis, 1947, Vol. IV, No. II, p. 16.
24 Bechtold, J. H., *Trans. A.I.M.E.*, 1953, **197**, 1,469.
25 Pugh, J. W., *Trans. A.S.M.*, 1955, **47**, 984.
26 Bechtold, J. H., and Shewmon, P. G., *Trans. A.S.M.*, 1954, **46**, 397.
27 Bechtold, J. H., *Acta Metallurgica*, 1955, **3**, 249.
28 Nash, J. W., Ogden, H. R., Durtschi, R. E., and Campbell, I. E., *Journal of the Electro-Chemical Society*, 1953, **100**, 272.
29 Sherby, O. D., Anderson, R. A., and Dorn, J. E., *Trans. A.I.M.E.*, 1951, **191**, 643.
30 French, R. S., and Hibbard, Jnr., W. R., *Trans. A.I.M.E.*, 1950, **188**, 53.
31 Jenkins, W. D., and Digges, T. G., *Journal of Research (N.B.S.)*, 1952, **49**, 167.
32 Carreker, Jnr., R. P., and Hibbard, W. R., *Acta Metallurgica*, 1953, **1**, 654.
33 Jenkins, W. D., and Digges, T. G., *Journal of Research (N.B.S.)*, 1950, **45**, 153.
34 Jenkins, W. D., and Digges, T. G., *Journal of Research (N.B.S.)*, 1952, **48**, 313.
35 Carreker, Jnr., R. P., *Trans. A.I.M.E.*, 1957, **209**, 112.
36 MacGregor, C. W., *Journal of The Franklin Institute*, 1944, **238**, 111 and 159.
37 Jenkins, W. D., Digges, T. G., and Johnson, C. R., *Journal of Research (N.B.S.)*, 1955, **54**, 21.
38 Dorn, J. E., Pietrokowsky, P., and Tietz, T. E., *Trans. A.I.M.E.*, 1951, **191**, 933.
39 Geil, G. W., and Carwile, N. L., National Bureau of Standards, May 7th, 1952, Circular 520, p. 67.
40 Hauser, F. E., Starr, C. D., Tietz, L., and Dorn, J. E., *Trans. A.S.M.*, 1955, **47**, 102.
41 McAdam, Jnr., D. J., *Trans. A.I.M.E.*, 1949, **185**, 727.
42 Bechtold, J. H., *Trans. A.I.M.E.*, 1956, **206**, 142.
43 Carreker, Jnr., R. P., and Guard, R. W., *Trans. A.I.M.E.*, 1956, **206**, 178.

News in Brief

ASSOCIATED ELECTRICAL INDUSTRIES, LTD., has received an order from the Yorkshire Electricity Board for an eleven-panel 33kV. metalclad switchboard to be installed at Scunthorpe South substation. This will be a regional control centre and an important 132/33 kV. grid supply point. Four of the feeders controlled by this switchgear will provide additional supplies at 33 kV. to the Appleby Frodingham steelworks, thus making another contribution by A.E.I. to the needs of the steel industry.

THE directors of Hilger & Watts, Ltd., announce that their company has acquired the whole of the issued share capital of Microwave Instruments, Ltd. The two companies have been collaborating for over a year in the development of measuring apparatus for electron spin resonance.

THE Newcastle upon Tyne area sales office of Alcan Industries, Ltd., (formerly Northern Aluminium Co., Ltd.) has been moved to new premises at Newgate House, Newgate Street, Newcastle upon Tyne. The telephone number is changed to Newcastle upon Tyne 22107 but the Telex number, 21917, remains unchanged.

BRITISH OXYGEN have agreed with the Board of Trade to lease a site near Dumbarton on which to establish progressively a new light engineering factory, while leaving the oxygen plant manufacturing at the existing Edmonton Works. It is estimated that over two years will elapse before the first stage of the new factory is established. Thereafter, there will be a gradual build-up to a total labour strength of about 2,000 during the following three to four years.

FURTHER production increases resulting from the recently enlarged electronics department have enabled George Kent, Ltd., to deliver Mark 3 electronic strip chart recorders in eight weeks and at the same time to reduce the price. The largest reduction, in the case of the 16 point instrument, is from £437 to £355.

THE Incandescent Heat Co., Ltd., have received an order from Cooper & Turner, Ltd., of Sheffield, for two shaker hearth furnaces. One will be used for normalising rivets and the other for hardening bolts that are direct quenched from the shaker hearth. Both of these furnaces are gas-oil fired, using the new R.I.M.P.A. high duty burners.

WORK on the steel rolling mill project at Jinja is reported from Uganda by Barclays Bank D.C.O. to be well on schedule, and it is expected that the buildings will be completed by the end of November when the installation of machinery will begin. A railway line has already been laid to the site and it is planned to have the factory in production by July, 1962.

A Magnetic Tester for the Measurement of Interlayer Air-Gaps Between Steel Reinforcing Bands of Pressure Vessels

By J. W. Walley, A.M.I.E.E., A.R.T.C.S.

Research Department, A.E.I. (Manchester), Ltd.

This article describes the development of a new non-destructive testing device designed to give magnetically an approximate indication of the air-gap length between ¼ in. thick steel reinforcing bands used to strengthen a large steel pressure vessel. When a powerful magnet is placed on the near side of a band some magnetic flux passes across the air space on the far side into an adjacent band or shell plate. A change in the air-gap length varies this flux, which in turn affects the main flux passing through the test zone. The change in main flux is then shown as a change in the external field strength between the magnet poles on a moving magnet magnetometer. The tester reads average gap directly from 0 to 0·060 in. to within about ±20% provided certain test conditions obtain. The tester is simple and portable, requires no special skill to operate and is independent of electrical supplies.

1. Introduction

THE problem of measuring magnetically the air-gap between ¼ in. steel plates from one side only was encountered in connection with the proposed reinforcement of reactor pressure vessels by the AEI–John Thompson Nuclear Energy Co. Ltd. (now The Nuclear Power Group, Knutsford, Cheshire). The plates were to be used to form a series of multiple-plate reinforcing bands or hoops, 2 ft. 6 in. wide, embracing the barrel portion of a 3 in. thick steel fabricated pressure vessel 50 ft. in diameter and 80 ft.[1] high. This method of strengthening the vessel is more economical in many respects than a straightforward increase in shell plate thickness as a means of permitting a higher circuit pressure and thus obtaining a greater output from the same size of nuclear reactor.

From theoretical design considerations[2] and from experience with a scale model pressure vessel, it was manifest that successful reinforcing would depend to a large extent on the superposed ¼ in. plates being in close contact with each other. Any interlayer air spaces which occurred would have to be kept small in length in order to avoid excessive local expansion of the vessel when under pressure. Hence the need for a simple non-destructive device to indicate the magnitude of the interlayer gaps formed during the wrapping procedure.

Several alternatives to a magnetic method were considered, such as ultrasonics, resonant-frequency vibration, and X-ray and gamma-ray techniques, but none of these appeared capable of producing a really practical device. Simply tapping the ¼ in. plates with a small hammer detects the presence or absence of air-gaps by the "hollowness" of the note but, of course, gives no indication of gap length.

The use of magnetic means to evaluate the air-gap is based on the idea that a variation in gap length between two magnetic surfaces will function as a variable reluctance affecting the magnitude of magnetic flux passing across the gap from an external source such as a U-shaped magnet. Previous experience in the detection of lamination faults in steel sheet[3] suggested that such a scheme might succeed provided that: (*a*) the ¼ in. test plate could be magnetised to near saturation; and (*b*) the range of air-gap variation envisaged could be detected as a variation in field strength at the surface of the test plate between the magnet poles. Although there were many obvious uncertainties associated with a magnetic method, it was appreciated that a high degree of accuracy was unnecessary. It was decided, therefore, to initiate some preliminary tests with an existing design of permanent magnet and using a Silmanal element probe magnetometer to detect the field changes. These were carried out and formed the basis on which the new tester* was designed.

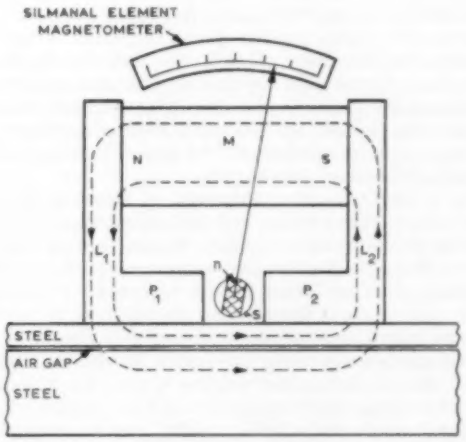


Fig. 1.—Schematic arrangement of magnetic gap tester.

2. Principle of Operation

The magnetic gap tester is shown diagrammatically in Fig. 1 which depicts a test on the interlayer gap between the first reinforcing plate or lamination and the pressure vessel wall or shell. A strong magnet *M* of high-energy material is provided with soft iron pole-shoes *P*1, *P*2 which are applied to the outer surface of the ¼ in. plate, making as close a contact as possible. Magnetic flux from the magnet is then apportioned between the main path along the plate and a parallel leakage path across the air-gap into the shell, according to the gap reluctance.

* Pat. applied for.

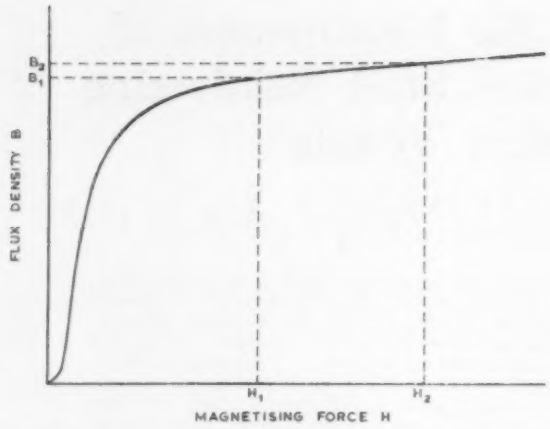


Fig. 2.—Typical magnetisation curve shape for steel plate.

With little or no gap the leakage flux spreads appreciably, whereas with a large gap the spread is limited by the high reluctance of this gap. Hence, the flux density in the $\frac{1}{4}$ in. plate varies with air-gap length and produces a corresponding variation in the external field strength between the pole-shoes, this being readily detected by a moving-magnet magnetometer[4] designed to measure field strength differences (see Fig. 1).

Fig. 2 illustrates the advantage of working the steel plate above the "knee" of the magnetisation curve towards the saturation region. It can be seen that for a given change in flux density a much greater corresponding change in magnetising force is required. The spacing of the pole-shoes is therefore arranged so as to produce a magnetising force of the order of 100 Oersteds with zero air-gap, and by using the control spring as a "torsion head" the magnetometer pointer is set back to zero on the scale. Then, known gap changes (as caused by non-magnetic shims behind the plate) can be equated to magnetometer readings of field change for calibration purposes.

In order to apply or remove the magnetic field and so facilitate manipulation of the tester, a magnetic shunt is applied across the upper ends of the magnet limbs, thus providing "on-off" control. During this operation the magnetometer is slid away from the interpolar space to avoid violent deflections of the pointer as the flux changes occur.

3. Preliminary Laboratory Tests

In order to establish fairly quickly the potentiality of the magnetic method of gap measurement it was decided to experiment with the existing lamination detector referred to previously. A $\frac{1}{4}$ in. thick bright steel plate, $4\frac{1}{2}$ in. wide by 11 in. long, was placed on the machined face of a 3 in. thick steel block, and non-magnetic shims of varying thickness formed known air-gaps between the interfaces. The calibration curve is shown in Fig. 3, and although the changes in the magnetometer deflection were small the results showed that the method was practicable on a $\frac{1}{4}$ in. thick test plate. Greater sensitivity than this was clearly required if it could be achieved without sacrificing magnetometer robustness.

A similar test was made with a stronger magnet and using a standard Silmanal magnetometer to measure the field strength changes between the pole-shoes. The magnet was a hand unit which embodied 3·5 in. of Alcomax with hinged pole-shoes spaced 0·9 in. apart. The curve obtained from the results is the centre one in Fig. 4, and when compared with Fig. 3 it demonstrates the gain in sensitivity arising from higher magnetisation. Furthermore, with higher values of field strength a magnetometer having a stronger control spring and robust pivots may be employed. Thus, the initial concept of plate magnetisation approaching saturation was borne out by these early calibration tests.

It was found that by reducing the pole-shoe spacing to 0·2 in. a high value of field strength was obtained under

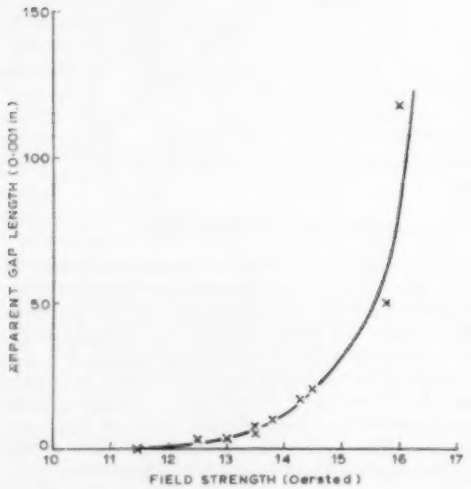


Fig. 3.—Calibration curve with lamination detector.

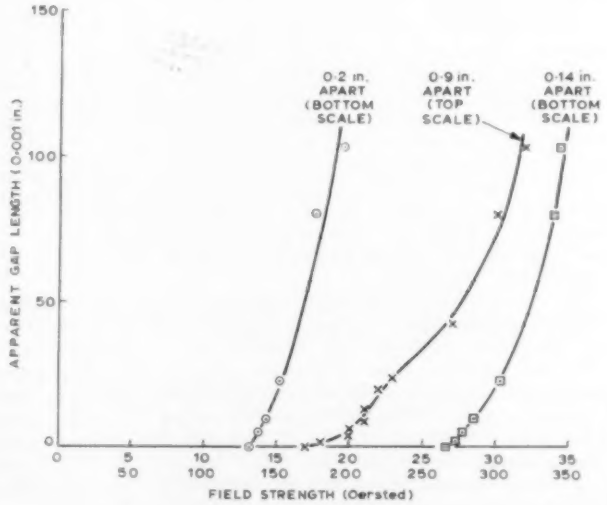


Fig. 4.—Effect of magnet pole spacing on field strength.

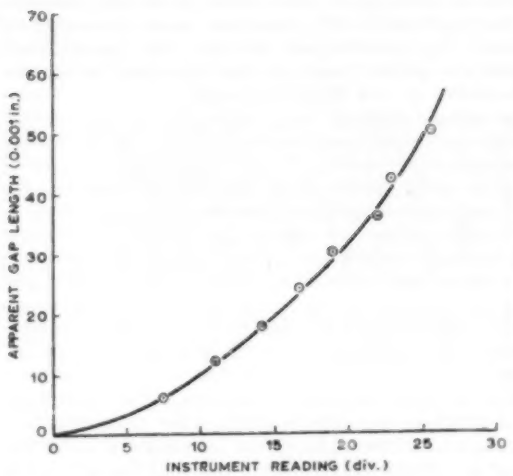


Fig. 5.—Calibration curve with biased magnetometer.

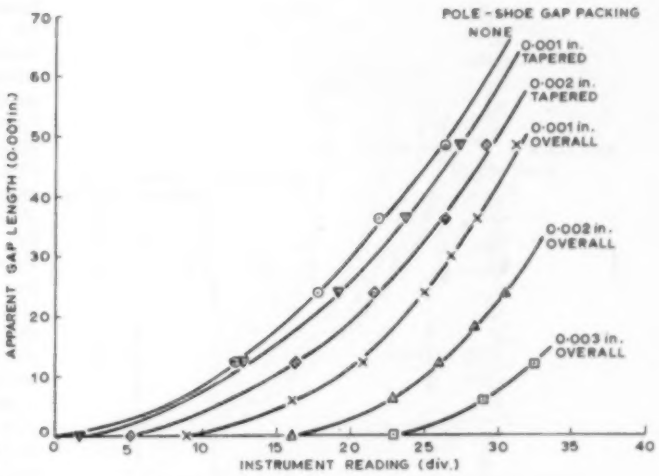


Fig. 6.—Effect of pole-shoe contact on calibration.

zero gap conditions commensurate with the desired magnetic saturation of the test plate. Calibration tests showed correspondingly high field strength changes for known air-gap variations. With the spacing reduced still further to 0·14 in. the value of field strength at zero gap was again raised above that for the 0·2 in. setting.

These calibration curves are shown in Fig. 4, which also indicates the effect of pole-shoe spacing on the interpolar field strength values. The advantages of narrower spacing are shown by the higher initial field and by greater field changes for the same changes in air-gap length. It was decided that with the 0·2 in. spacing the applied magnetic field was sufficient to produce the high flux density required in the test region, whilst the appreciable field changes allow the use of a high range magnetometer of robust design.

Ideally, the magnetometer should respond only to field strength changes over and above that of the zero gap condition in order to utilise the whole of the scale length. One possible method of achieving this was to bias the pointer behind zero by using the zero adjuster as a "torsion head." The amount of bias would be such that the magnetometer would read zero on the scale for the zero gap condition value of field strength.

A standard AEI magnetometer was modified for this purpose by fitting a wide angle zero adjuster which could be locked in position. The probe was reduced in length in order to mount the magnetometer in the 0·2 in. long interpolar gap of a new permanent magnet fitted with fixed pole-shoes having a pole face area 1·75 in. × 2·35 in. This combination of "on-off" controlled magnet and biased magnetometer formed a portable unit with which to apply further calibration tests. The magnetometer incorporated three small Silmanal magnets instead of the usual one, and gave an unbiased full scale deflection of 30 divisions in a field of 200 Oersted.

Several tests were made using a $\frac{1}{4}$ in. thick steel bar 4 in. wide × 12 in. long as the reinforcing plate, and three 1 in. thick plates to represent the 3 in. thick shell. Copper sheets each 0·006 in. thick were used as non-magnetic packers in the air-gap, the magnetometer having been set to read zero with no packing present. The results showed the efficacy of the biased zero in expanding the readings across the scale over the expected range of air-gap conditions. The corresponding calibration curve is shown in Fig. 5. This typical curve shape shows graphically how the sensitivity of the tester to interlayer gap change is reduced asymptotically as the total gap increases in value.

During tests in the laboratory and on site, serious trouble was experienced with this unit from unexpected changes in the magnetometer zero setting. This was eventually attributed to the effect of the violent deflections of the magnetometer element occurring when applying and removing the magnetic shunt. It was decided, therefore, to arrange the magnetometer in guides so that it could be slid into the interpolar gap when testing and slid out whilst positioning the tester or operating the shunt. The sliding magnetometer technique functioned satisfactorily, giving reasonably reproducible results with a $\frac{1}{4}$ in. thick ground steel plate 12 in. × 11 in. laid on the machined face of a 3 in. thick shell plate of the same size. For this size of test rig it was found necessary to increase the sensitivity of the magnetometer to give full scale for 100 Oersteds.

At this stage, experience indicated that under the idealised conditions of the ground flat $\frac{1}{4}$ in. test plate the gap tester would give consistent and reasonably accurate results. Under practical conditions, however, involving rough plates, it was clear that the readings would be influenced adversely by variable factors such as surface finish, pole-shoe contact, gap area, and magnetic properties of the test plate. It was decided, therefore, to investigate the effect of these factors on the performance of the tester before proceeding with further tests on curved plates.

4. Factors Affecting Performance

4·1 *Pole-shoe Contact*

Early tests showed clearly that this variable factor had a more adverse effect on the tester results than any other. The principle of the tester depends on the detection of a change in the value of the magnetic field in the interpolar gap and such a change may be caused by a variation in the magnetic reluctance of the joint

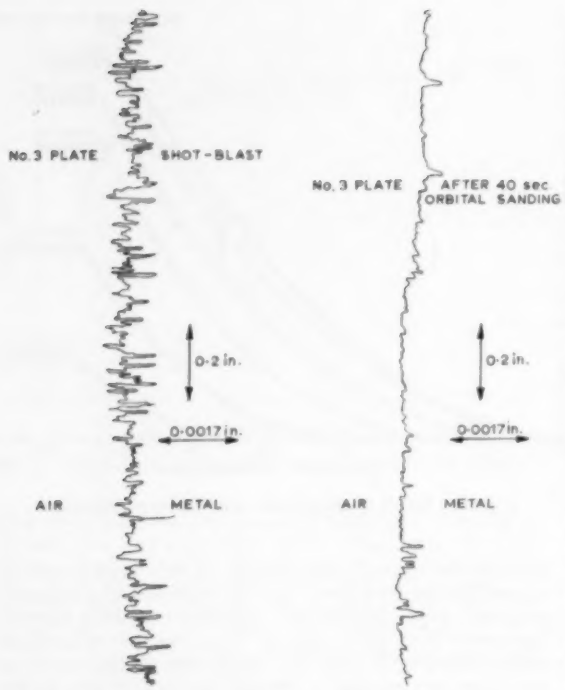


Fig. 7.—Talysurf records on shot-blast plate before and after orbital sanding.

between the pole-shoes and the test plate surface. This variation could then effectively mask any change due to the interlayer air-gap which was present.

The effect of the pole-shoe joint reluctance on calibration was determined with the ground flat $\frac{1}{4}$ in. plate and the machined 3 in. block. Paper packers 0·001 in. thick were interposed between the pole-shoe and the test plate surface to simulate poor contact. The calibration curves obtained are shown in Fig. 6. It can be seen that the curve shapes are substantially the same but have different origins, dependent on the pole-shoe to test plate joint efficiency. With poor contact the zero point may be shifted appreciably up the scale, although the deflection from this off-set zero is more or less the same for a given change in the interlayer gap.

The ease with which large errors may be introduced by small variations in pole-shoe contact is shown clearly by the calibration curves of Fig. 6. However, it was argued that in practice even a casual contact between clean metal surfaces free from grit, scale, etc. would not make a joint as bad as that of overall separation by the 0·001 in. packer. Hence the calibration tests with tapered gaps under the pole-shoes formed by packing along one edge only. The resultant curves showed that both tapered gaps, i.e. 0·001 in. (av. 0·0005 in.) and 0·002 in. (av. 0·001 in.) were appreciably better than the overall 0·001 in. gap, thus confirming the above argument.

Although the tapered pole-shoe gap tests were reassuring it was obvious that the magnetic tester could never give reliable results unless the pole-shoe contact remained invariable at the standard obtaining during calibration. Two unsuccessful attempts were made to reduce the effect of pole-shoe joint variations. In the first method a flexible magnetic joint was formed under the pole-shoe by the application of a magnetic paste consisting of carbonyl iron powder and grease. The results were unsatisfactory due mainly, it was assumed, to the low permeability ($\mu = 5$–10) of the paste.

The second method was analogous to the ballast resistance principle in an electrical circuit. By deliberate enlargement of each pole-shoe joint length with a relatively thick non-magnetic shim it was hoped that a given variation would have a less proportionate effect on the tester reading. Unfortunately, known joint variations although superposed on the thicker shim were not less effective than without the shim. This result is also borne out to some extent by the curves of Fig. 6, where the zero displacement for each 0·001 in. step of packing shows no sign of diminishing with increased total packer thickness.

With the tester calibrated on the ground flat $\frac{1}{4}$ in. plate and applied to a rusty or scaled $\frac{1}{4}$ in. plate, the zero displacement corresponds to the average gap under the pole-shoe. Tests showed that even with recently shot-blast plates surface cleaning was necessary to obtain consistent results. Talysurf measurements were made on a typical shot-blast surface before and after cleaning with an electrically driven orbital sander fitted with medium emery cloth. These records are reproduced in part in Fig. 7. The zero displacement was reduced by this 40 seconds' cleaning process from about 15 divisions to an acceptable 1 or 2 divisions. The standard of a satisfactorily prepared surface was determined in accordance with B.S.1134 (1960) and found to be 40–50 micro-in. C.L.A.

In practice, of course, the $\frac{1}{4}$ in. plates are curved to a 25 ft. radius so that with plain pole-shoes 5 in. long × 1·75 in. wide the gap tester is most effectively applied with the pole width tangential and the length axial. Even so, this "line contact" constitutes theoretically an average gap under the pole-shoes of about 0·0005 in., which may be reduced by either correctly curved pole-faces or by grinding flat the test zone area. Whether or not these steps would be necessary for reliable gap testing could be shown by calibration tests involving cleaned curved plates.

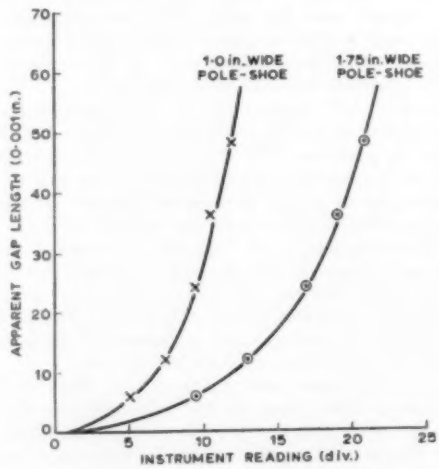


Fig. 8.—Effect of pole-shoe width on calibration.

One proposed method of improving the contact of plain pole-shoes on a curved plate was to reduce the width to, say, 1 in. with the length unchanged. Then at a radius of 25 ft. the difference between the arc and the tangent over 1 in. would be negligible. A second complete tester was therefore constructed with pole-shoes tapered to 1 in. width but otherwise identical to the first tester. Although of similar magnet strength the testers gave widely different calibration curves when compared under ground-flat plate conditions (see Fig. 8). Thus, the narrower pole-shoe limited the useful range of the gap tester and it was decided to continue the tests with the first unit having the 1·75 in. wide pole-shoes.

4·2 *Magnetic Properties of the Reinforcing Plate Material*

The possibility of a wide variation in magnetic permeability occurring between individual ¼ in. plates and batches of plates was foreseen at the outset. A change in permeability will be superposed on the magnetometer reading and appear as a change of air-gap length, the higher the permeability the lower the reading, and vice versa. Hence, a wide range of varying permeabilities might introduce errors in air-gap readings large enough to invalidate the magnetic method.

In order to evaluate the spread of permeability likely to be experienced in practice it was decided to obtain magnetisation curves on several specimens of plates from a variety of suppliers but conforming to the reinforcing plate specification B.S. 1501–154. In all 23 specimens were tested, but for the sake of clarity only the minimum, maximum and mean value curves are plotted in Fig. 9.

Hardness figures obtained on the specimens were, in general, related to the magnetic properties. In the cases shown in Fig. 9 the lower and higher curves correspond, respectively, to Brinell hardness numbers 138 and 112. For several of the ¼ in. test plates the magnetisation curve and the corresponding interlayer gap calibration curve were available for comparison, but there was no apparent correlation over the range investigated. Plates with closely similar magnetisation curves gave different calibration curves and vice versa.

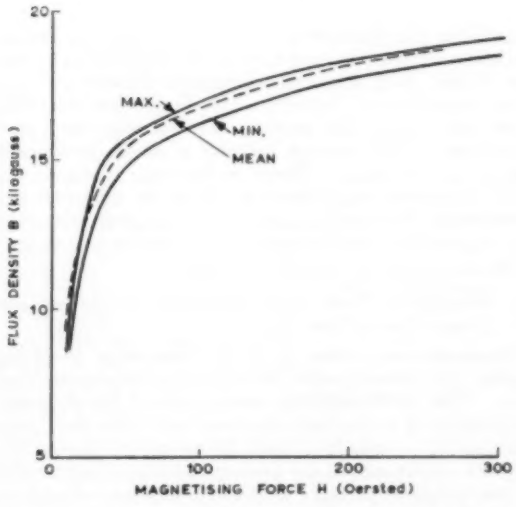


Fig. 9.—Maximum, minimum and mean magnetisation curves of all specimens tested.

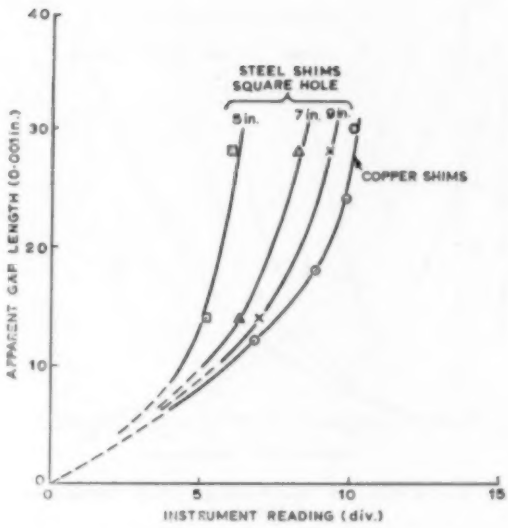


Fig. 10.—Effect of gap area on calibration.

The inference from these test results was that whilst strict uniformity of magnetic properties was not of paramount importance, the "spread" should nevertheless be confined to that found by experiment and as indicated in the curves of Fig. 9. If necessary, the Brinell hardness test could be applied to individual plates as an indirect guide to magnetic suitability.

4·3 *Effect of Interlayer Gap Area*

This was determined with the ground-flat ¼ in. plate and the machined flat 3 in. steel block. Square holes of various sizes were cut in the 0·014 in. thick magnetic steel sheets which were inserted in turn between the ¼ in. thick plate and the block to form a known interlayer gap (0·014 in.) of varying area. The insertion of two similarly cut sheets at the same time gave the effect of area on twice the gap. The readings are compared in Fig. 10 with a calibration curve obtained using copper shims to separate completely the test plate from the 3 in. block. It can be seen that sensitivity diminishes with gap area causing errors in gap length readings which become serious below, say, the 9 in. square or equivalent area level.

4·4 *Effect of Variations in Reinforcing Plate Thickness*

For these tests calibration curves were obtained after each successive reduction in thickness by grinding on the same flat steel plate bolted to the machined 12 in. × 11 in. face of the 3 in. thick shell plate. The curves are given in Fig. 11 which shows the degree of error likely to be introduced by plate thickness variations into the gap tester readings based on a 0·250 in. plate calibration.

The estimated tolerance was stated as being 0·250 +0·025 in. −0·000 in. giving a range approximately represented by the 0·250 in. and the 0·280 in. curves of Fig. 11. With a gap tester calibrated on a test plate of average thickness of 0·263 in. the errors would be reduced without altering the tolerances quoted. Thus, calibration on a reinforcing plate of average thickness is preferable and, if possible, deviations in plate thickness from this average should be avoided.

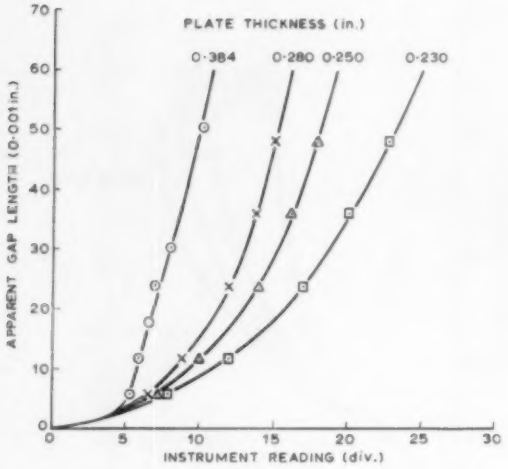


Fig. 11.—Effect of reinforcing plate thickness on calibration.

4·5 *Magnet Limb Size*

Flux measurements on the gap tester indicated that the magnet limbs L_1L_2 (see Fig. 1) were operating at a high flux density with a consequent loss of magnetising force otherwise available for magnetisation of the test plate. In order to determine the effect on sensitivity of reducing this loss extra soft iron was fitted to the limbs to give about twice the cross-sectional area. Calibration tests made with and without the extra section gave results with insignificant differences showing that there was little to be gained by enlarging the magnet limbs.

5. Laboratory Tests With Shell Plate

Whilst the large-scale test rig, described later, was being constructed, calibration tests were continued with the 12 in. × 11 in., 3 in. thick machined flat plate, and also with a piece of typical 3 in. shell plate, rolled to the correct curvature, 18 in. square. Several ¼ in. thick steel plates 12 in. × 12 in. were shot-blast and drilled at the corners to coincide with threaded holes in each of the above shell plates. Then any ¼ in. plate could be bolted down against either the machined flat surface or the rough curved surface of a shell plate for calibration tests. With a flat shot-blast ¼ in. plate pulled down against a typically finished and curved shell plate it was hoped to obtain a good mechanical zero condition under which to set the gap tester zero before calibration with the known copper shims. Furthermore, a comparison could be made of calibration curves on different ¼ in. plates in both flat and curved condition.

TABLE I.—EIGHT POSITION REPRODUCIBILITY TESTS WITH GROUND-FLAT PLATE

Air-Gap Packing (thou.)	Gap Tester Readings (div.) for Following Positions								Average Reading (div.)	Maximum Variation from Average	
	1	2	3	4	5	6	7	8		−%	+%
nil	1·0	2·5	1·0	1·5	1·5	3·0	0·8	2·2	1·7		
6	9·5	10·2	10·0	9·3	9·9	12·2	10·0	11·8	10·4	10	17
12	12·1	14·0	13·2	13·1	13·3	15·2	13·2	14·4	13·6	11	12
24	17·0	18·8	17·5	17·2	16·8	19·6	17·6	18·5	17·9	6	10
48	19·1	24·0	20·1	21·0	20·1	23·8	20·8	22·4	21·4	11	12

5·1 *Calibration Tests with Ground-Flat ¼ in. Plate and Machined-Flat 3 in. Shell Plate*

Prior to this series of tests the gap tester was placed directly on the machined surface of the 3 in. shell plate in order to set the magnetometer zero under a condition representing complete absence of an interlayer air-gap. Then calibration was carried out in the normal way with the ¼ in. plate bolted to the 3 in. shell and using the known copper shims to set the interlayer gap. At each gap setting it was decided to take eight readings at roughly 45° intervals round the central position on the test plate. The results are summarised in Table I and the calibration curve plotted to the average readings of all the positions is shown in Fig. 12.

The results show the variations in readings obtained on the same interlayer air-gap tested from different angles under the "idealised" conditions obtaining with a

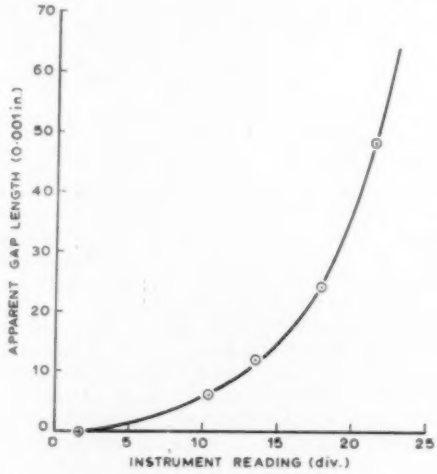


Fig. 12.—Average calibration curve of eight position tests on ground flat plate.

ground-flat ¼ in. plate on a machined-flat 3 in. shell plate. The low readings obtained with no packing are an indication of the joint magnetic reluctance formed between clean interfaces in contact. The maximum variation above and below the average reading expressed as a percentage of the average reading is shown in the last column of the table. These values may indicate the order of accuracy to be expected from the magnetic gap tester under favourable conditions. Alternatively, they may represent a true variation in interlayer gap as seen by the gap tester at each test position.

5·2 *Calibration Tests with Shot-Blast ¼ in. Plate and Rough Curved 3 in. Shell Plate*

Numerous tests were made at this stage involving various ¼ in. plates pulled down on to the curved shell plate. This work markedly demonstrated the difficulty of establishing a zero gap condition with this shell plate which could be reproduced with different ¼ in. plates. The magnetic reluctance of the average interlayer gap formed by two irregular surfaces in contact was too variable to ensure that the gap tester zero setting on a particular plate would hold for other plates. In addition it was

doubtful whether the air-gap condition chosen for the zero setting was in fact the minimum likely to occur in practice. The calibration curves obtained were of similar shape to the curve of Fig. 12, but displaced to the left or right of zero due to the above-mentioned variable.

A Talysurf recording which was obtained on the surface of the rough 3 in. shell plate is shown in Fig. 13, the magnitude of the surface irregularities being indicated by the scale. This recording and those of Fig. 7 are an indication of the interlayer air-gap conditions obtained between a shot-blast $\frac{1}{4}$ in. plate on a rough 3 in. shell plate and also between individual shot-blast $\frac{1}{4}$ in. plates. In either case a mechanical zero with the " high-spots " in contact clearly corresponds to an irregularly shaped air-gap of finite magnetic reluctance as seen by the gap tester. Three interesting calibration curves obtained with shot-blast $\frac{1}{4}$ in. plate No. 7 are shown in Fig. 14.

Curve *A* was obtained with the gap tester set to zero when placed directly on the machined surface of the 3 in. shell plate as for the tests in Section 5·1. Plate No. 7 was bolted to the shell plate and the centre portion of the exposed surface was cleaned for testing with the orbital sander. With " zero " gap, i.e. no packing, the interlayer gap reluctance was certain to be greater with the shot-blast $\frac{1}{4}$ in. plate than with the previous ground-flat plate: hence the gap tester reading of about 10 divisions corresponding to the average gap length with no packing. From this point, however, the curve is similar in shape to those starting at zero. This indicates that the gap tester tends to respond to change of interlayer air-gap rather than the total gap, at least over a limited range of zero gap conditions.

Calibration on Plate 7 as above but resetting to zero for the " no packing " condition resulted in Curve *B* which is substantially parallel to Curve *A*. Curve *B* also shows a marked similarity to that obtained from the ground-flat plate tests as shown in Fig. 12.

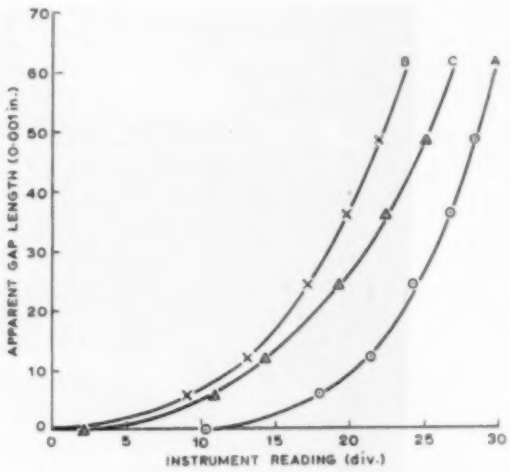


Fig. 14.—Calibration curves on Plate No. 7.

Curve *C* was obtained with Plate No. 7 bolted down against the rough curved shell plate, the zero setting remaining as for Curve *B*. The reading of between 2 and 3 divisions with no packing indicates a greater average interlayer gap than existed with the machined shell plate used to set the magnetometer zero. The gap tester readings as shown by Curve *C* are noticeably greater than those of Curve *B* for the higher values of interlayer gap.

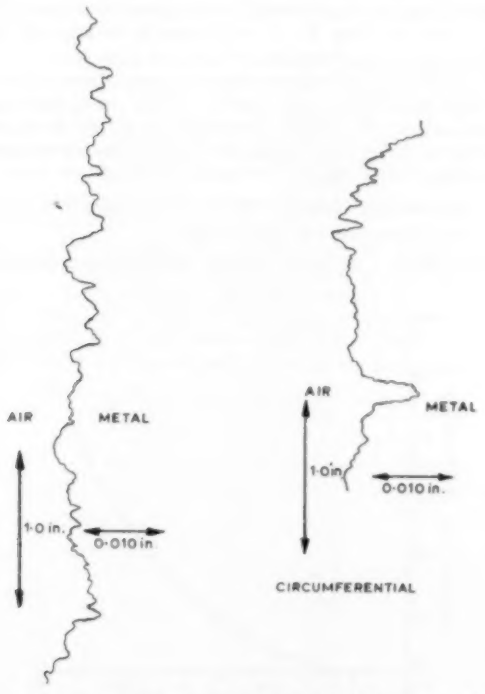


Fig. 13.—Talysurf records on typical rough curved 3 in. shell plate.

5·3 *Multiple Layer Tests With $\frac{1}{4}$ in. Shot-blast Plates and Machined-flat 3 in. Shell Plate*

These tests were carried out with $\frac{1}{4}$ in. plate No. 7 as the test plate and the ground-flat $\frac{1}{4}$ in. plate as the preceding plate, other plates being interposed between these and the machined 3 in. shell plate. The results showed that the gap tester calibration held irrespective of the number of plates below the test plate, provided that the interlayer gap immediately preceding the test gap did not exceed the order of 0·030 in. This confirms previous work where small gaps under the plate preceding the test plate made little difference to the tester readings. The effect of a large preceding gap is to shift the zero point up the scale, the change in reading for a given change in the test gap length being substantially the same. For example, with a preceding gap of 0·045 in. the zero shift was 3 divisions.

6. Tests With a Large-scale Test Rig

6·1 *Description of the Test Rig*

In order to simulate more realistically the practical conditions of test it was decided to construct a test rig incorporating full-size wrapping plates. A piece of typical 3 in. curved shell plate, 10 ft. long (circumferential) × 3 ft. wide (axial), was mounted with the width vertical between steel supports fitted with castors. Various 2 ft. 6 in. wide wrapping plates fitted with lifting hooks could be positioned against the outside curvature of the shell plate prior to clamping down.

On the test rig the wire ropes passed through channel

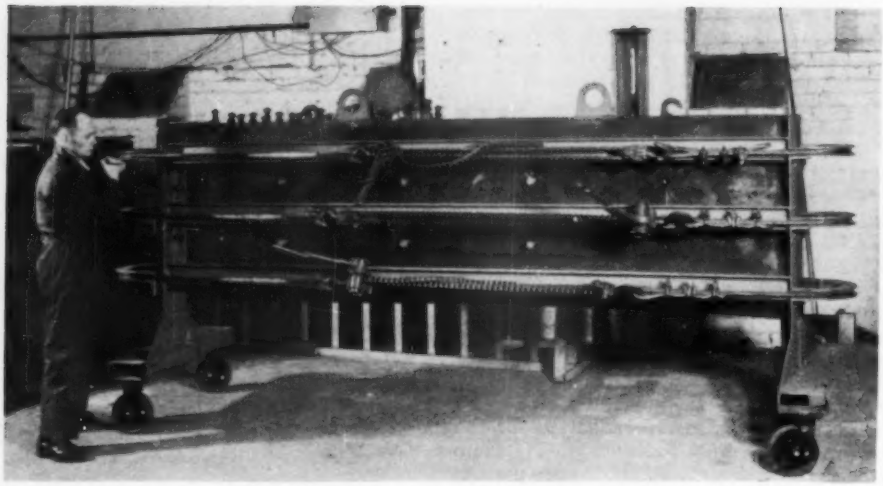


Fig. 15.—Rear view of large scale test rig.

guides at each end of the shell plate and were linked at the rear by the pull-lift blocks, as shown in Fig. 15. Each block was capable of exerting a pull of 3 tons. This view of the test rig shows the horizontal bracing girders fitted as a precaution against distortion of the shell plate under pressure and also visible are the 1 in. B.S.F. jack screws used to deflect the wrapping plate from the underside. These screws were fitted with non-magnetic tips.

Most of the work done with this test rig involved one typical wrapping plate and the shell plate. The wrapping plate had a rusty and corrosion-pitted surface due to exposure, but was cleaned up for the tests by shot-blasting. Even so, the test surface conditions were worse than with the new shot-blast plates used in the laboratory. Before commencing the tests the mating surfaces of the wrapping plate and the shell plate were wiped down with an oily rag to remove grit and also for lubrication. Otherwise these surfaces were not treated in any way.

6·2 *Selection of Test Zones*

The pulling-down technique consisted of gradually increasing the tension on each pull-lift block with simultaneous hammering of the wrapping plate using a 4 lb. nylon hammer to help " bedding-down." From the pitch of this hammering note it was possible to distinguish between contacting and non-contacting zones. A high pitch, as when striking the shell plate directly, indicated interfaces in contact and no air-gap, whereas a low pitch or " hollow " sound indicated no contact and an air-gap.

It was found that a wrapping plate when tightened down invariably made contact at several local zones corresponding to " high-spots " on the shell plate. Between these " no gap " zones the striking technique indicated the presence of interlayer gaps. An ultrasonic flaw detector was used to check the " no gap " zones using a direct transmission technique from the wrapping plate surface to the inside surface of the shell plate. Transmission occurred only where the interfaces were in contact, which agreed with the striking method. The ultrasonic tests showed that the areas in contact were small, suggesting again a " high-spot " on the shell plate.

The " bedding down " of the wrapping plate was not improved by extra leverage on the pull-lift block handles since much of the additional force was lost in friction at the wire-rope guide channels.

6·3 *Preliminary Calibration Tests*

Preliminary tests showed that in order to obtain sensible results the test zones would require grinding prior to orbital sanding. A portable electric disc grinder was therefore passed lightly across the selected area before final cleaning with the orbital sander. One of the " no gap " zones detected by striking was prepared in this way for a calibration test using the 0·006 in. thick copper shims used previously, the gap tester zero remaining as set on Plate No. 7 for Curve *B* in Fig. 14. The calibration curve obtained is shown in Fig. 16.

A calibration test was made at a zone adjacent to one of the 1 in. B.S.F. jack screws. Since each turn corresponded to an actual movement of 0·100 in. it was possible to deflect the wrapping plate by known amounts according to the angle of rotation of the screw head.

6·4 *Correlation Between Gap Tester, Depth Micrometer and Screw Thread Indications*

Two other " no gap " zones were selected for tests

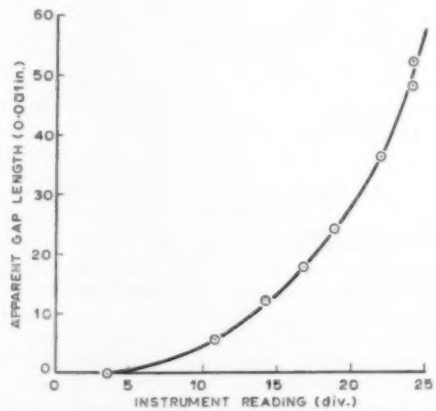


Fig. 16.—Calibration curve on zone 3 of large scale test rig.

designed to correlate indications of interlayer gap length by depth micrometer with gap tester readings and jack screw rotation. Four small holes for the micrometer probe were drilled in the wrapping plate at points forming the corners of a 5 in. square enclosing each test zone. These test zone surfaces were cleaned by grinding and orbital sanding as described previously.

Before positioning the wrapping plate the depth micrometer was used to determine plate thickness at each exploratory hole. Then with the wrapping plate tightened down micrometer readings were taken at each hole, and by subtracting plate thickness from these values a measure of the air-gap length was obtained. Gap tester readings were taken on each zone and converted into gap length values with the calibration curve of Fig. 16. The jack screw at each test zone was also used to indicate gap length. All readings were repeated with the jack screws rotated slightly so as to deflect the wrapping plate and increase the interlayer gap.

The results showed that the variation in depth micrometer readings was commensurate with an irregular surface on the shell plate, the values being largely dependent on whether a depression or a "high-spot" occurred at the point chosen for the exploratory hole. There was good agreement between the gap tester and the jack screw readings but neither of these agreed satisfactorily with the average depth micrometer readings.

Discounting the depth micrometer readings as unrealistic made the results more encouraging, since agreement existed between the mechanical gauge (jack screw thread) and the magnetic gap tester. Whilst the screw thread had sufficed so far as a guide to average gap length it was clear that a more accurate and preferably direct reading gauge was necessary.

6·5 *Correlation Between Gap Tester, Clock Gauge and Shimming Indications*

One proposed method was to use a clock gauge to measure the outside surface height of the wrapping plate above the shell plate surface at several points. Then by subtracting the wrapping plate thickness a measure of the interface air-gap length could be obtained. This scheme was rejected because in addition to being laborious it was felt that background errors would render the results unreliable.

It was decided to use the clock gauge to indicate directly the wrapping plate deflection at the test zone centre due to non-magnetic packers inserted into the interlayer gap. To obtain a zero gap condition for calibration purposes it was necessary to select test zones where the interfaces were known to be in contact when

TABLE II.—COMPARISON OF INDICATIONS OF INTERLAYER GAP LENGTH BY CLOCK GAUGE, NON-MAGNETIC SHIMS AND GAP TESTER ON LARGE SCALE TEST RIG

Test Zone	Air-Gap Packing (thou.)	Gap Change by Clock Gauge (thou.)	Gap Tester Average Reading (div.)	Gap Length from Ground Plate Curve (thou.)	Total Average Gap Length (thou.)
1	nil	0	5·5	2·0	
	6	5·5	11·8	8·0	7·5
	12	11·7	15·5	16·0	13·7
	24	23·7	18·8	27·5	25·7
	36	35·7	21·0	42·0	37·7
	48	48·3	23·0	70·0	50·3
	60	61·3	23·5	75·0	63·3
2	nil	0	10·0	5·5	
	6	5·5	13·3	10·5	11·0
	12	11·5	15·7	16·5	17·0
	24	23·5	18·6	27·0	29·0
	36	35·5	20·9	42·0	41·0
	48	48·0	21·4	48·0	55·5
	60	60·0	23·0	70·0	65·5

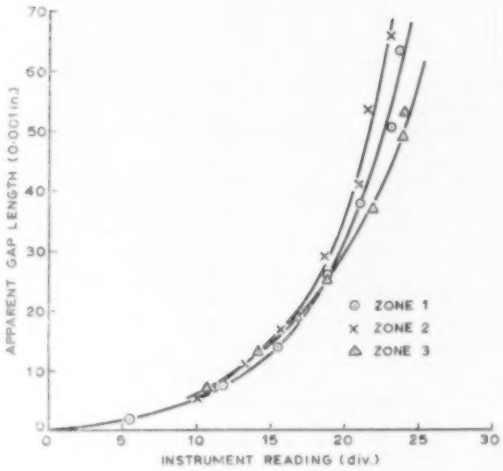


Fig. 17.—Calibration curves at three positions on large scale test rig.

the wrapping plate was fully clamped with no packing. These were test zones 1 and 2 as used previously and requiring, therefore, only a light orbital sanding before commencing the tests.

The clock gauge was supported over the wrapping plate by means of a rigid steel bridge clamped to the shell plate adjacent to the test zone. With no packing and the wrapping plate fully clamped a gap tester reading was taken and the gap tester removed. The clock gauge was then clamped to the bridge with the probe end touching the wrapping plate at the centre of the test zone and the dial was adjusted to read zero. The wrapping plate was released sufficiently to insert a 6 in. × 12 in. × 0·006 in. thick copper shim behind the test zone before clamping down again. Then the clock gauge registered directly in thousandths of an inch the change in the interlayer gap caused by the shimming. The clock gauge was removed and the gap tester reading corresponding to the increased gap was noted. This procedure was repeated with additional packing shims, the clock gauge registering each increase in gap over the previous value. Thus, calibration was accomplished on two test zones based on clock gauge readings and known packing shims. The test results are summarised in Table II. The close agreement between the clock gauge readings and the known air-gap packers established the reliability of the shimming technique of providing known gap changes. Several gap tester readings were obtained at each-gap setting, the mean values (as given in the table) being used for calibration purposes.

For minimum air-gap conditions in both test zones the gap tester gives a positive reading corresponding to the average gap length between the interfaces. Thus, although several high points may be in contact the tester indicates an average gap greater than that used to set the magnetometer zero, i.e. No. 7 ¼ in. shot-blasted plate surface against the machined 3 in. shell plate surface.

The values of gap length obtained by applying the gap tester readings to Fig. 12 calibration curve are shown in the table. In general, this gives values above the gauge readings, the greatest discrepancies occurring with the larger gaps. Fig. 12 curve may be used to evaluate the small initial gap which when added to the observed gap

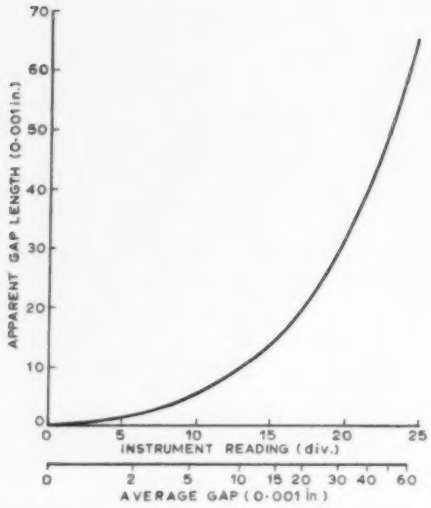


Fig. 18.—Mean calibration curve on large scale test rig.

changes gives the total average gap lengths required for calibration. These are shown in the last column of Table II and the calibration curves are given in Fig. 17, together with zone 3 curve (Fig. 16) corrected by adding the initial gap.

Thus, three calibration curves were obtained at different positions on a typical full-size reinforcing plate under practical conditions and with the gap tester on a vertical surface. The mean curve shown in Fig. 18 was taken as the best representation of the gap tester performance under various conditions, and was used to mark the magnetometer scale to read directly the average gap length in thousandths of an inch.

Fig. 19 shows a gap length measurement being made on the large scale test rig. The magnetic shunt has been removed and the magnetometer slid into the magnet gap to give a direct reading of interlayer gap length.

The results of the large scale test rig experiments showed that the magnetic method of interlayer gap measurement was feasible provided that the test conditions and testing procedure were correct. It can be seen that there was good agreement between the calibration curves shown in Figs. 12, 14 and 18. Fig. 12 curve was obtained from several tests on a ground-flat $\frac{1}{4}$ in. plate and a machined-flat 3 in. shell plate. Fig. 14 Curve *B* relates to shot-blast Plate No. 7 on the machined-flat 3 in. shell plate. Fig 18 shows the mean curve obtained on the rough $\frac{1}{4}$ in. reinforcing plate in the large scale test rig. Thus, three $\frac{1}{4}$ in. plates differing widely in origin, surface finish and test conditions gave substantially the same calibration curve.

7. Experience With The Unit

In demonstrating the usefulness of the gap tester sensible results were obtained when it was realised that an absolute zero interlayer gap as seen by the tester was a rare occurrence. Usually, the average initial gap as indicated by the gap tester had to be added to the values of the known gap changes made during the demonstration.

From time to time a quick check was made for changes in the gap tester calibration due to frequency of application, handling, transportation, etc. This comprised simply reverting to the zero setting condition with Plate No. 7 on the machined 3 in. shell plate and observing the gap tester reading. Then any serious deviation from zero would indicate a change in either magnet strength or magnetometer sensitivity. In fact these zero variations were so small as to be negligible. This was taken as a good indication of magnet stability and magnetometer reliability.

8. Future Development

In its present form the gap tester has served its original purpose of determining the feasibility or otherwise of the magnetic method of interlayer gap measurement, and experience with the device has shown where further development work would be advantageous.

The magnetic test would be simpler to apply if the test zone surface required no preparation. It has been shown that with surface contact variations the calibration curve zero point changes in accordance with the level of field strength in the magnet gap. Therefore, some form of compensator based on this level of magnet field is required to keep the magnetometer zero point unchanged. The use of a small magnet incorporating a normal magnetometer has been suggested to indicate magnetically the test zone surface condition to be allowed for when using the gap tester.

At present, adequate cleaning of the test zone is essential and improvements in the form of fixtures for

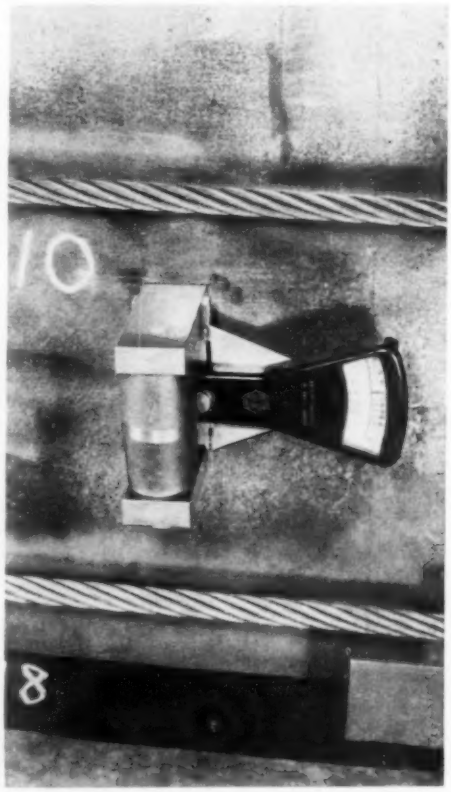


Fig. 19.—Close-up of tester showing direct reading scale.

grinding or sanding the surface would probably speed up this process and help to give the required degree of surface finish.

9. Conclusions

The magnetic method of providing an approximate indication of the interlayer air-gap length between the $\frac{1}{4}$ in. thick steel bands on a reinforced pressure vessel is feasible provided certain test conditions obtain. These are as follows :—

(*a*) A good contact between the gap tester pole-shoes and the $\frac{1}{4}$ in. test plate (average gap less than 0·001 in.).

(*b*) No wide variation in the magnetic properties of the $\frac{1}{4}$ in. reinforcing plates.

(*c*) No wide variation in the thickness of the $\frac{1}{4}$ in. plates.

(*d*) Interlayer gap area not less than the equivalent of a 10 in. square.

(*e*) Calibration of the gap tester under standardised conditions corresponding as closely as possible to those of test.

(*f*) Strict adherence to the correct cyclic operation of the gap tester.

Under ideal conditions, such as obtain with ground-flat surfaces, the magnetic gap tester will give reproducible results with a fairly good order of accuracy, but under practical conditions it is doubtful whether an accuracy of better than $\pm 20\%$ will be obtained.

The magnetic gap tester responds to the average metal-to-metal gap between the irregular interfaces of magnetically permeable material, no allowance being made for non-magnetic coatings such as paint, rust-proofing, scale, etc. on the mating surfaces.

The spring-biased Silmanal magnetometer is a satisfactory means of indicating the change in level of the interpolar magnet field associated with the interlayer gap variations. A more linear scale would be advantageous if this could be achieved by simple means. In view of the estimated accuracy of the tester there would be no advantage at present in extending the scale beyond the existing 30° arc.

The modern high-energy permanent magnet with "on-off" control is a satisfactory means of providing the steady magnetic field for testing. This type of magnet operated cyclically tends to provide a constant magnetic flux rather than a constant magneto-motive force, and is therefore more suitable than an equivalent D.C. electromagnet. The permanent magnet also has the obvious advantage of requiring no electrical supply and eliminating the electric shock hazard.

Acknowledgments

The author wishes to thank Sir Willis Jackson, F.R.S., Director of Research and Education, AEI (Manchester), Ltd., for permission to publish this article. Thanks are also due to Messrs. D. L. K. Bowers, S. W. Redfearn and E. S. Tanner of the Research Department, AEI (Manchester), Ltd., for their enthusiastic collaboration and to Mr. M. W. Jervis and his colleagues of The Nuclear Power Group for their encouragement and many helpful suggestions.

REFERENCES

1 Mantle, K. G., Marshall, N., and Palmer, P. J. "Experimental Investigation into the Stress Distribution in a Band Reinforced Pressure Vessel." *Proc. I. Mech. E.*, 1959, **173**, 123.

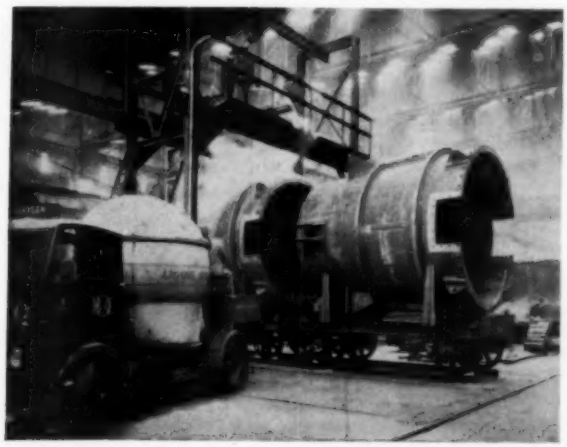
2 Gill, S. S., and Lakin, R. W. "Design of a Reinforced Cylinder for a Nuclear Reactor Pressure Vessel." *Proc. I. Mech. E.*, 1960, **174** (29).

3 Armour, A. M. "The Detection of Rolling Defects in Sheet Steel." *Metallurgia*, 1956, **54** (326), 301–304.

4 Armour, A. M., King, A. J., and Walley, J. W. "Some Developments and Simplifications in Permeameters." I.E.E. Monograph No. 20, January 1952, p. 7.

Ladle Trunnion Pins Nitrogen Shrunk

EIGHT steel trunnion pins, each over 2 ft. in diameter, were nitrogen shrunk to fit four 100 ton ladles recently at the Teesdale Ironworks of Head Wrightson & Co., Ltd. To fit the ladle bores, the diameter of the pins was shrunk by an average of 0·04 in. A light, 2 ft. deep, insulated tank made to hold the liquid nitrogen supplied by British Oxygen, could be moved on rails above the ladles which were set up on bogies. By means of a 2 ton electric hoist, each pin was lined up with the ladle bore and then raised while the liquid nitrogen tank was positioned underneath. The pin was lowered into the tank and immersed in liquid nitrogen pumped direct from a B.O.C. road tanker. On average, each pin was immersed for about fifty minutes, and a total of 1,230 gallons of liquid nitrogen was used. Nitrogen shrinking was the most economical and only practical way of fitting the trunnions. Heating the ladle bore would have been much more difficult and costly and taken a great deal longer. There would also be a danger of distortion of the ladle.



Liquid nitrogen being delivered by B.O.C. road tanker for the shrinking of ladle trunnion pins prior to fitting.

ORDERS for Efco furnaces to a value of approximately £70,000 have recently been obtained by Efco (Sth. Africa) (Pty.), Ltd. The orders cover an electrically heated closed-quench furnace, a pit type gas carburising furnace, a continuous mesh belt conveyor furnace and two bogie hearth furnaces, each rated at 750 kW. The bogie hearth furnaces are to be suppled to South African Railways for normalising, annealing and stress relieving steel castings. They will take loads up to 8 tons.

400 kV Power Link Across the Thames

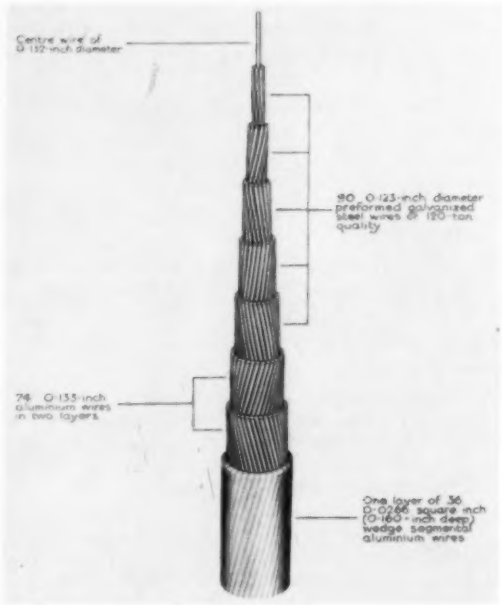
Largest Steel-Cored Aluminium Conductors in Supergrid

WITH the erection and installation of the 400 kW. overhead power link spanning the Thames between West Thurrock, Essex, and Swanscombe, Kent, an important link has been forged in the supergrid, as it will provide a vital extension of the existing supergrid north of the river, through the C.E.G.B.'s new 1,000 MW. steam generating station being built at West Thurrock, to connect with new lines to Canterbury, Lydd, the Cross-Channel Link, and the nuclear power station now under construction at Dungeness. The double-circuit link incorporates six steel-cored aluminium conductors and a similar earth wire. These are the largest of their kind ever used as an overhead power transmission line forming part of the British supergrid.

The main features influencing the design and height of the four towers of the crossing were the 4,500 ft. length of the main span and a Port of London Authority requirement of a minimum clearance of 250 ft. between the lowest point of the conductors in the span and mean high water level. The two suspension towers, constructed of galvanised high tensile steel, are 630 ft. high and weigh some 436 tons each. Set 1,600 ft. back from the suspension towers are the anchor towers, which are 145 ft. high and weigh 99 tons each. The total route length of the crossing is thus 7,700 ft. and the precision of the siting of the four towers is such that they are aligned to within $\frac{1}{4}$ in. The British Insulated Callender's Construction Co., Ltd., as main contractors to the C.E.G.B., have been responsible for the co-ordination of the design and for the erection of all materials for the crossing, with the exception of the foundations. The four towers were designed by Blaw-Knox, Ltd., and the crossing and anchor towers fabricated by Horseley Bridge & Thomas Piggott, Ltd., and Painter Bros., Ltd. (a member of the B.I.C.C. Group), respectively.

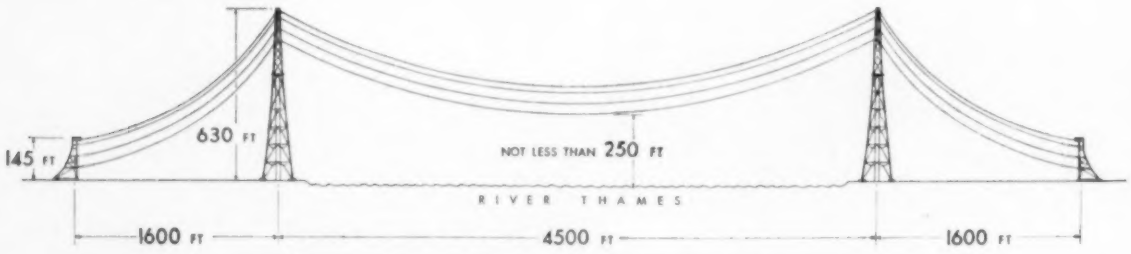
The Conductors

The steel-cored aluminium conductors were designed in collaboration with the C.E.G.B. by the Wire Mill Division, of British Insulated Callender's Cables, Ltd., who were responsible for their manufacture. Considerable assistance was afforded by Rylands Brothers, Ltd., of Warrington, who collaborated in the actual manufacture. The conductors, which are designed for 400 kV. transmission, consist of 90/0·123 in. diameter preformed galvanised steel wires of 120-ton quality and a centre wire of 0·132 in. diameter. This steel core is surrounded by 74/0·133 in. aluminium wires in two layers and a layer of 36/0·0266 sq. in. (0·160 in. deep) wedge segmental aluminium wires. The purpose of the latter is to present a smooth outer surface to reduce aerodynamic effect over the large spans. The overall diameter of the completed conductor is approximately 2·214 in., and the nine lengths supplied include two spares.


Centre wire of 0·132-inch diameter
90 0·123-inch diameter preformed galvanized steel wires of 120-ton quality
74 0·133-inch aluminium wires in two layers
One layer of 36 0·0266 square inch (0·160-inch deep) wedge segmental aluminium wires

Sketch of conductor showing individual layers.

Specially designed conductor accessories—including armour rods, corona-bells and dead-end terminations—



Sketch showing the crossing and its towers—not to scale.

Conductor suspender approaching north tower.

Fitting vibration dampers in crossing span at north tower.

were developed by Alcan Industries, Ltd. The 6 ft. long dead-end fittings are similar to the usual Noralgrip type, consisting of a steel forging to hold the steel core, and an aluminium sleeve to carry the current and take some of the load. These fittings were subjected to type-tests to B.S. 215 Pt. 2, carried out at the National Coal Board's laboratories at Bretby, near Burton-on-Trent, which showed them to be well within the safety limits required for the crossing.

Stringing the Conductors

The stringing of the six conductors and the similar earth wire across the 4,500 ft. main span and the 1,600 ft. anchor spans posed a number of problems. Of these, the most notable were weight and length—each conductor weighs 21½ tons and is 7,754 ft. long—and the condition in the contract which requires that no conductor should touch land or water at any stage, owing to the possibility of damage by corrosion or abrasion. Such damage could give rise to corona losses and television reception interference. The attachment of clamps and haulage devices to the conductors during erection was also prohibited for similar reasons. In view of these considerations an overhead track rope with a special suspension trolley system was used for erection.

Because of the nature of the crossing, and the heavy tensions involved, compression type dead-end clamps were fitted to the conductors in the factory. This required accurate measurement of the conductor prior to fitting and a tolerance of ± 12 in. on the unstressed lengths of 7,754 ft. was worked to in manufacture by the B.I.C.C. Wire Mill Division.

At a time agreed with the Port of London Authority, the river was closed to allow the track and haulage ropes, previously laid in the river, to be winched up between the crossing towers. The period of closure permitted was four hours.

For the stringing operation, a 1¼ in. diameter fully locked coil aerial track rope was installed over carriages at the tops of all four towers and connected through tensioning tackles to the ground behind each anchor tower. Alongside and slightly above was installed a double length of $\frac{9}{16}$ in. diameter steel haulage rope connected to suitable winches sited at the backs of the anchor towers. Each conductor was laid in small rubber-lined bobbins attached to the end of 10 ft. long vertical booms suspended from twin wheeled carriages running on the track rope and clamped to the haulage rope, and was then pulled across the system under light tension. These suspenders were fed on at 80 ft. intervals and had to be removed at each crossing tower and replaced in the adjacent span. To carry the conductors themselves through the crossing towers, and to facilitate lowering them to their final position, a conductor cradle with two 5 ft. diameter rubber-lined sheaves at 26 ft. centres was hung from the top of the crossing towers just below the track rope.

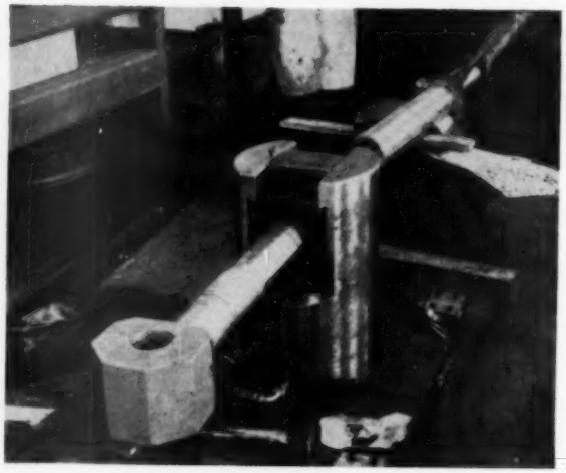
As the leading end of each conductor reached the far anchor tower, tension was applied at both ends to lift it clear of the suspenders. It was then lowered, by means of the cradle at the crossing towers and by bridled tackles down the faces of the anchor towers, to its final position when it was sagged. Tension insulator assemblies each weighing 3¼ tons, with a length of 24½ ft. and comprising eight strings of 20 × 12¾ in. diameter porcelain units in parallel were introduced and landed on the anchor towers—six on each. Armour rods were fitted to each conductor which was then placed in a saddle and attached to the crossing tower suspension insulator assembly. Each assembly comprises six strings of 20 × 14 in. diameter porcelain units in parallel, weighs nearly 3 tons and is 21½ ft. in length. Some indication of the magnitude of the tensioning operation is given by the fact that the erection tensions involved were of the order of 30 to 35 tons per conductor.

After installing each conductor the suspenders were returned to their starting points in preparation for the

next conductor of the same circuit. The conductors in each circuit were erected in the order, bottom, middle, top. After the stringing of the first circuit the track and haulage ropes were transferred to a similar position at the top of the towers above the second circuit. When this was completed the track and haulage equipment was moved to the centre of the towers for the erection of the earth wire.

When the first conductor was run out the time taken amounted to nearly two and a half days but this was subsequently improved upon to less than one day for later conductors. Under favourable conditions speeds of up to 25–30 ft./min. were achieved. Allowing for the time to set up and prepare the conductor drum, run the conductor, lower it to its final position, tension and sag, install tension and suspension insulator assemblies, and return the suspenders to the starting point, stringing was completed at the rate of about one week per conductor.

All operations were directed by VHF radio control and there were as many as six radio sets maintaining contact between teams on the ground and at the tower tops on both sides of the river.



Compressing steel dead-end : note aluminium sleeve positioned on conductor.

Elliott-Automation Analysis Department

ELLIOTT BROTHERS (LONDON), LTD., a member of the Elliott-Automation group, announces that it has created an automation analysis department within its data processing group of divisions. The company has accumulated extensive experience of both the " on-line " and " off-line " application of electronic computers to industrial processes through its computing service centres and through experience with " on-line " control installations by its computers both in this country and America.

The company states that in the great majority of cases it has found that there is no precise knowledge available of the true mathematical nature of industrial processes. This lack of knowledge of the nature of processes is one of the factors delaying the extensive introduction of complex automation systems. In America, Russia and certain other Eastern European countries the attitude adopted by industrialists is to install a computer to gather and evaluate the data available (and a number of Elliott 803 computers have recently been installed in those countries for this purpose) with the intention that when the true natures of the processes involved have been determined, the computers will be put on to their operational control. In Britain the immediate incentives to adopt this course of action do not exist, with the result that the introduction of automation is being delayed. To deal with this problem the automation analysis department of Elliott Brothers (London), Ltd., has been created under the leadership of Dr. L. C. Payne, to undertake the specialised studies involved in this kind of work.

New Home for D.B. Machine Tools

THE DAVID BROWN MACHINE TOOL DIVISION, which claims to design and build a wider range of high grade gear-cutting and gear-shaving machines than any other company in the world, has been steadily expanding its output (three-quarters of which is exported) and it became evident that more floor space would be needed than was available at Sherborne Street, Manchester. To meet this requirement, new premises have been acquired at Trafford Park, Manchester, with about three times the floor space, and transfer of equipment to the new works was effected during the annual works holiday in August.

Exporting by Air

THE problem of transporting £18,000 worth of sensitive instrumentation to another continent was profitably solved recently by the Cambridge Instrument Co., Ltd., when a fourth Microscan X-ray analyser was delivered to its associate company in the U.S. Previous deliveries of Microscan analysers (weight 1 ton) to the Illinois Institute of Technology, the United States Steel Corporation and the Crucible Steel Co. had been made by the normal sea route at a cost of £686, with delivery times of approximately 9 days from factory to installation site.

It was found that transport via the normal B.O.A.C. Atlantic Cargo Service would take less than a quarter of this time and that total costs would be cut by £310 : freight being reduced from £363 to £296, insurance from £73 to £30 and packing from £250 to £50. A Cambridge representative was able to inspect the loading arrangements before take-off, and, in contrast to the specially-made wooden packing cases required for the sea journey, dust-proof plastic coverings were the only protection necessary. This was due to the short period the instrument would be in transit and the reduced number of loadings and unloadings, all of which could take place with company experts in attendance.

Twenty-four hours after leaving Cambridge the Microscan cabinets were fork-lifted from the B.O.A.C. aircraft at Idlewild airport and shortly after were being installed in the works of the Cambridge Instrument Co., Inc., New York, where prospective customers may now submit their own samples for analyses and reports, so that the potentialities of the instrument may be evaluated with respect to individual requirements. A similar advisory service has been in operation in England since July 1960.

A Versatile Furnace for Isothermal Annealing and Normalising

By R. G. Bretherton, A.I.M.

Leyland Motors, Ltd.

The principles underlying martempering, austempering and isothermal annealing are well-known. Reference to the isothermal transformation diagram for any steel reveals whether or not it is practical, on a commercial scale, to apply to that steel any of these treatments. This article describes the construction and operation of a furnace designed primarily for the isothermal annealing, normalising and high temperature stress relief of steel stampings used in the production of heavy commercial road vehicles.

ISOTHERMAL annealing may be carried out in the temperature range extending downwards from the Ar_1 temperature for approximately 150° C. The practical considerations which govern the application of isothermal annealing to a given steel are firstly, that at the temperature coincident with the desired ultimate hardness, the isothermal transformation characteristics shall show a useful delay period before transformation starts; and secondly, that once started, transformation shall not be unduly prolonged before being completed. True isothermal annealing is seldom possible on a commercial scale, because the time taken for the austenitised steel to cool down to the selected transformation temperature is greater than that used during the construction of the relevant isothermal transformation diagrams. Although this slower cooling rate may result in some premature transformation, the fact remains that for a number of commonly used alloy case-hardening steels and low-alloy medium-carbon steels, "commercial" isothermal annealing offers advantages in cost, and in consistency of hardness and microstructure, over the traditional normalising and softening treatments. The microstructure of such steels, when isothermally annealed, consists of well separated and uniformly distributed ferrite and pearlite. Such a structure is highly desirable for the majority of machining operations. It should be mentioned in passing that for certain applications, a succession of salt bath treatments has been admirably adopted for isothermal treatment.

General Features of New Furnace

To combine the advantages of isothermal annealing and at the same time to eliminate residual forging stresses, Leyland Motors, Ltd., have recently commissioned a continuous double track pusher type furnace, designed and built by British Furnaces, Ltd. The facilities with which the furnace is provided permit a variety of isothermal-annealing, normalising and full

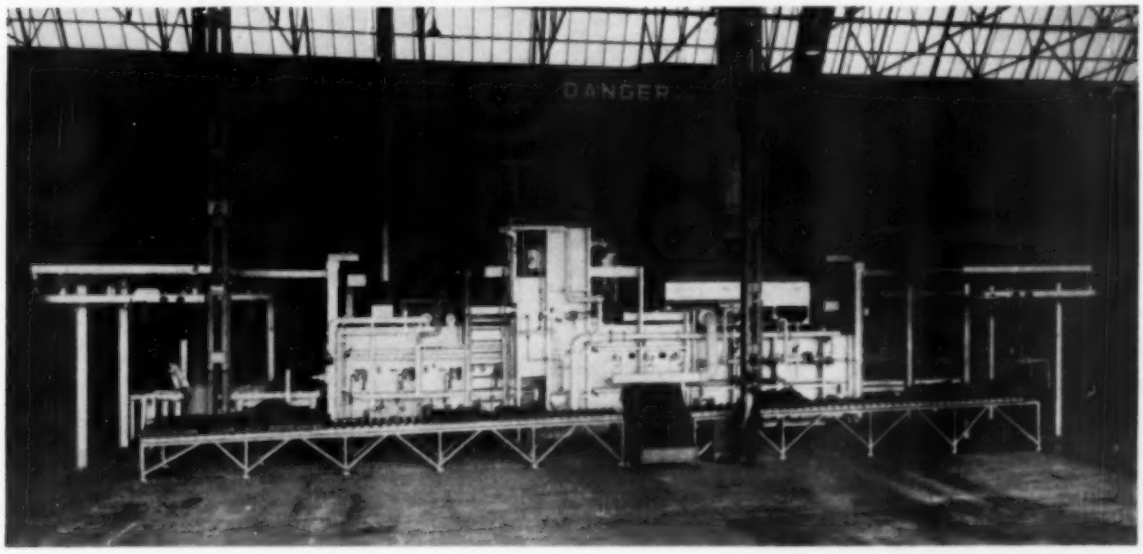


Fig. 1.—Side view showing tray return track and charge tipping unit.

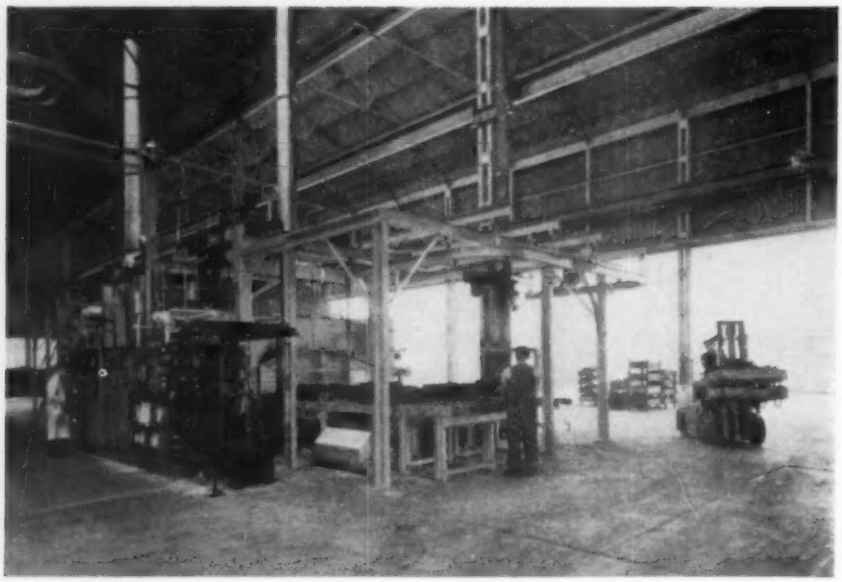


Fig. 2.—Charge end showing tray transfer system and control panels.

annealing treatments to be carried out at will. Within the furnace are three separate chambers. In the first (zones 1 and 2), the charge is heated up to, and then soaked at, the austenitising temperature. The centre chamber (zone 3) is of special interest. In it, the atmosphere can be rapidly circulated and heated or cooled as required. The zone is completely isolated in order to prevent thermal flow from one chamber to another. The special equipment included in this chamber enables the previously austenitised charge to be cooled quickly and uniformity to the selected isothermal transformation temperature without undercooling. In the last chamber (zones 4 and 5), the isothermal transformation temperature is maintained until the charge approaches the discharge doorway. As an alternative to isothermal annealing, the cooling equipment of the centre chamber may be used to cool the charge continuously through the critical range, thereby providing a normalising cycle, final cooling taking place in the last chamber. As a further alternative, the centre chamber may be completely by-passed to permit the charge to be cooled at a slower rate inside the last chamber.

The rated capacity of the furnace is 1,200 lb. net per hour. Experience has shown that this is a conservative figure: under appropriate conditions of section size and steel specification it can be safely exceeded.

Three general views of the furnace are to be seen in Figs. 1–3, and a plan view of the furnace and tray return system is shown in Fig. 4. Empty trays are loaded with untreated stampings at the low end of the inclined roll conveyor and are then picked up by a power hoist and tractor unit suspended from a monorail track and transferred to the furnace charge table extension. From this point, the trays are pushed manually along the charge table until protrusions on the trays are engaged by the pushing dogs of the charge pusher. Once engaged, the trays are pushed through the furnace automatically. At the discharge end of the furnace, trays carrying the treated stampings are picked up by a second overhead monorail assembly and transferred on to the high end of the inclined roll conveyor where the cooling of the load is completed. When cold, samples from each tray are Brinell tested before the trays are pushed along to the pneumatically-operated charge-tipping unit which empties them into storage boxes.

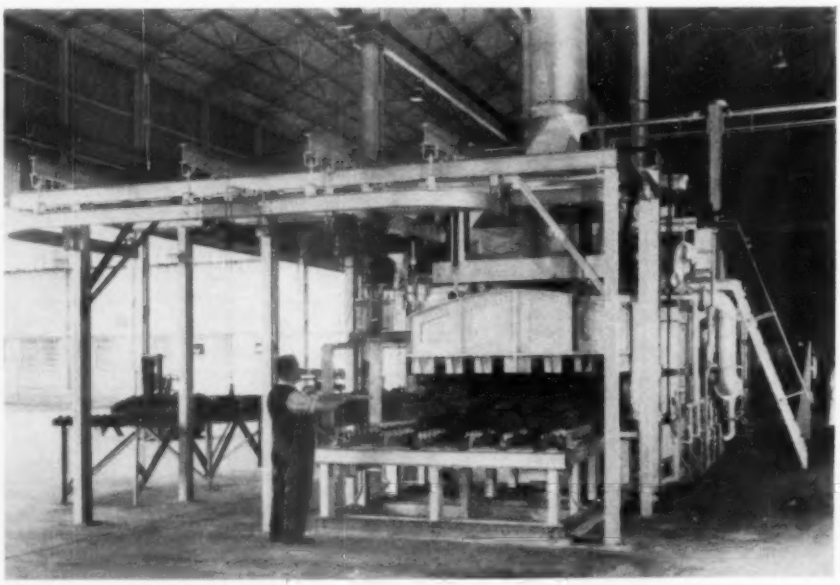


Fig. 3.—Discharge end showing tray transfer system.

Stampings falling within the correct hardness range are despatched to stores to await machining.

Furnace Zones

Within the furnace are five separately controlled zones. These are designated as follows :—

Zone 1—Heating zone.

Zone 2—Soaking zone.

Zone 3—Forced air circulation cooling and holding, or continuous cooling zone.

Zone 4—Holding or accelerated cooling zone.

Zone 5—Holding or normal cooling zone.

The longitudinal section through the furnace shown in Fig. 5 indicates the position of each of the five zones. It will be seen that zones 1 and 2 are together in one chamber and zones 4 and 5 are together in another, whilst zone 3 is isolated from the adjacent zones by two pairs of baffle doors.

In the chamber housing the heating and soaking zones, the loaded trays are brought up to the required austenitising temperature and adequately soaked. The burners, set in the side walls, fire alternately above and below the charge. The upper burners are inclined upwards towards the roof, thus creating a reverberatory action, and the lower burners fire between the open brickwork of the piers supporting the roller rails. As the loaded trays are pushed along the chamber the demand for heat becomes less, and to accommodate this the burner capacities are correspondingly reduced.

The forced air circulation cooling and holding or continuous cooling zone (zone 3) is an important feature of the furnace and deserves special mention. It is separated from zones 2 and 4 on either hand by brickwork baffles up to the hearth track and baffle doors above. The zone is long enough to hold one tray on each track. Within the zone, facilities are provided which enable the temperature of a hot charge pushed in from zone 2 to be brought down evenly and fairly quickly to the required isothermal annealing temperature and thereafter held at that temperature until the cycle time expires and the next pushing cycle operates. Alternatively, for normalising operations, the charge whilst in zone 3 may be continuously cooled until the cycle time expires.

The cooling curves shown in Figs. 6 and 7 serve to illustrate the performance of the zone. For the purpose of obtaining these records, bars, drilled for the reception of a thermocouple, were placed in a convenient position on the work trays together with the components of the regular charge. Immediately on the transference of each loaded tray, complete with test bar, from zone 2 to zone 3, a thermocouple was inserted into the hole in the bar and left there until the cycle time expired. In Fig. 6 the recalescence point for En 352 material (1% nickel-chromium, case-hardening steel) is well defined, whereas for En 355 material (2% nickel-chromium-molybdenum case-hardening steel) it is not noticeable. The reason for this is that for En 352 material, complete transformation is accomplished quickly, whilst for En 355 material, the start of transformation is retarded and the complete transformation is extended over a long period.

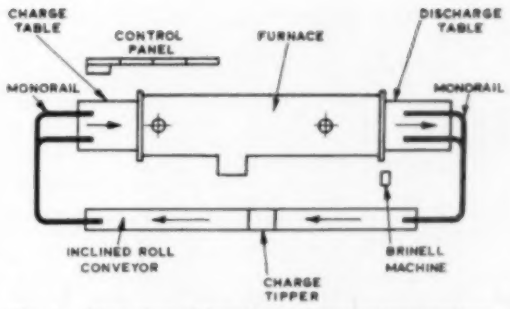


Fig. 4.—Plan view of furnace and tray return system.

Fig. 8 shows a section through the zone. The high speed fan revolves at approximately 2,400 r.p.m. and continuously circulates the furnace atmosphere within the zone. Heat can be added to or taken from this rapidly circulating stream, the mechanism for doing this being actuated by the temperature controller. Heat input is obtained from two large burners which fire into the top horizontal flue. Heat extraction is achieved when the atmosphere is diverted by means of a motorised damper through a bank of finned water-cooled tubes situated in a flue parallel to the main vertical flue. When the temperature of the circulating atmosphere is below control set point, the temperature controller causes

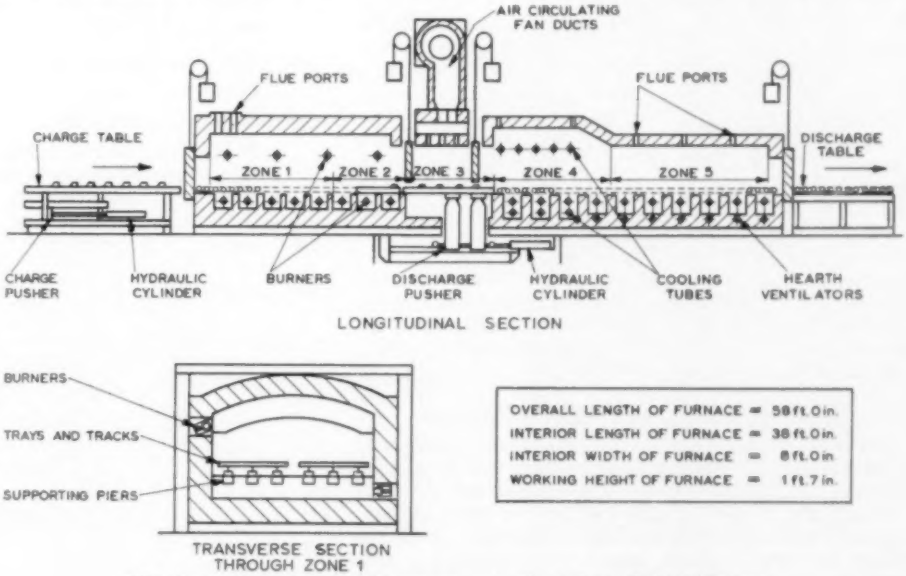


Fig. 5.—Longitudinal and transverse sections through the furnace.

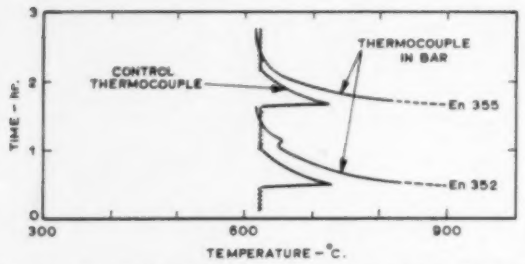


Fig. 6.—The cooling rates of 2 in. diameter bars of En 352 and En 355 steels whilst in zone 3 during isothermal annealing, using cycle A.

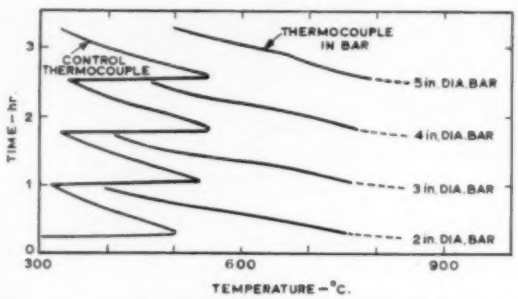


Fig. 7.—The cooling rates of bars of different diameters whilst in zone 3 during normalising, using cycle D.

motorised mechanisms to turn full on the main burners for zone 3 and to open the damper across the main vertical flue. With the temperature above control set point, the main burners are turned down to by-pass and the damper is closed across the main vertical flue. Explosion hazards are reduced by the employment of a Honeywell Protectoglo flame failure device. Its flame sensitive electrode is set in the path of the flame from one of the two pilot burners. When a flame is present the device permits solenoid valves in the gas lines to the main and pilot burners to be held open. Failure of the pilot flame results in the closing of both solenoid valves, thereby cutting off all gas supplies to the zone.

When operating on isothermal annealing treatments, zones 4 and 5 are used to maintain the charge at the selected transformation temperature previously established in zone 3. The burners in these zones are set alternately from side to side between the open brickwork of the roller rail supporting piers. Temperature uniformity within the chamber housing these two zones is achieved by appropriate adjustment of the following :—

(*a*) The heat input from each individual burner.

(*b*) The 26 flue ports located over the whole of the arch area.

(*c*) The hearth ventilators in zone 5.

The fact that the discharge door must always be open when the furnace is operating, inevitably leads to some fall in temperature within the chamber as the doorway is approached. However, this is minimised by a flexible asbestos curtain at the discharge opening.

Each of these zones is provided with facilities for the continuous cooling of the charge if required for normalising. In zone 4 a series of heat resisting alloy pipes are set across the furnace, five above and three below the charge. Through these pipes, air may be blown to provide the means for achieving an accelerated cooling rate for the charge. The blower providing this air is started automatically when the zone temperature exceeds control setting by 10° C. or more. The opening of the hearth ventilators in zone 5 enables the cooling of the charge to be continued.

Tray Movement Through the Furnace

Each of the two tracks through the furnace is made up of three sets of roller rails along which the work trays are moved simultaneously. The movement of trays through the furnace is achieved by two hydraulically-operated pushing units, one situated beneath the charge table, the other beneath zone 3. These pushing units work in sequence with the hydraulically-operated charge door and baffle doors. Three operating sequences are available for tray movement, these are designated as follows :—

(1) Zone 3 in use.

(2) Zone 3 by-pass.

(3) Test.

The operation of sequences "Zone 3 in use" and "Zone 3 by-pass" is fully automatic. The control is through a process timer. This can be set to the cycle time appropriate to the charge weight and heat treatment required.

A better understanding of the tray movement through the furnace may be obtained from the following brief description of the automatic sequence "Zone 3 in use." The order in which the movements occur on the expiry of the process timer are :—

(1) Baffle doors open.
(When closed, these isolate zone 3.)

(2) Discharge pusher operates.
(The pusher makes three strokes during which the two trays in zone 3 are moved forward into zone 4, pushing all remaining trays in zones 4 and 5 forward : simultaneously, two trays are pulled from zone 2 and left in zone 3.)

(3) Baffle doors close.

(4) Charge door opens.

(5) Charge pusher operates.
(The pusher makes four strokes, during which two trays on the charge table are pushed into zone 1,

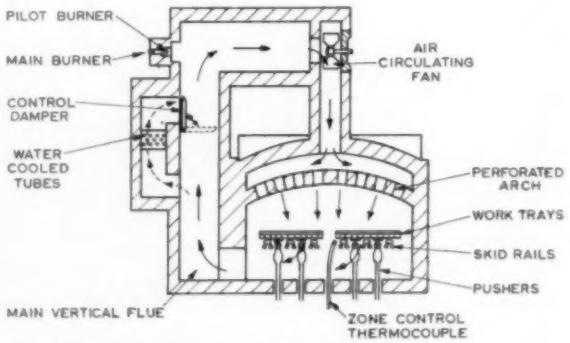
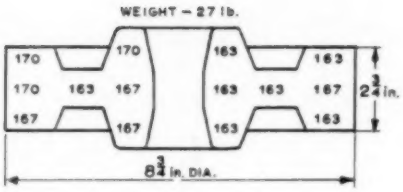
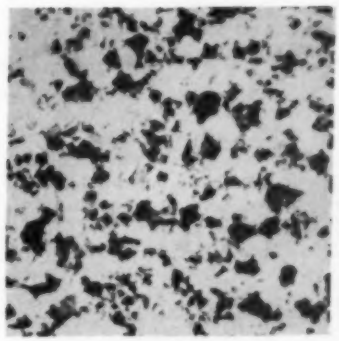
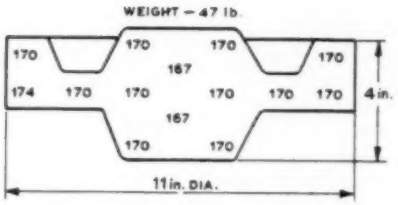


Fig. 8.—Transverse section through zone 3.

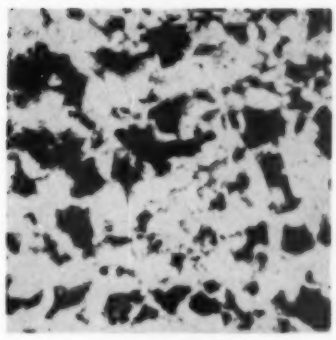


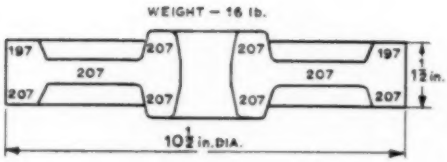
Gear in En 353 steel : treatment—cycle A (Table I)



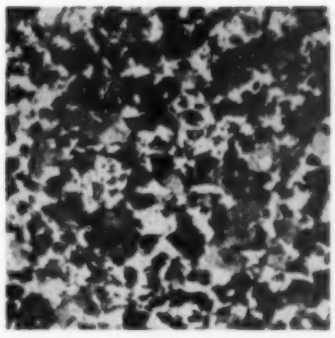


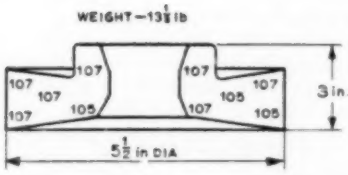
Gear in En 355 steel : treatment—cycle A (Table I)





Gear in En 19 steel : treatment—cycle B (Table I)





Pulley in En 1A steel : treatment—cycle C (Table I)

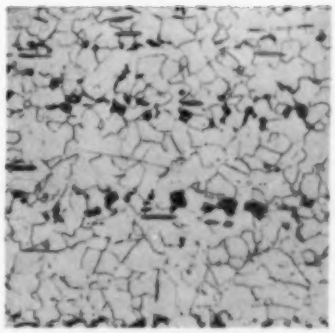


Fig. 9.—Hardness surveys and microstructures (× 100) of components treated in the new furnace.

these pushing forward all remaining trays in zones 1 and 2.)

(6) Charge door closes.

When using the sequence " Zone 3 in use " two trays, one on each track, are left in zone 3 for the duration of the cycle time set on the process timer. In the alternative automatic cycle " Zone 3 by-pass " the discharge pusher makes six complete strokes, thereby pushing one tray on each track from zone 2, through zone 3 into zone 4, zone 3 remaining empty. Switching to the " Test " position enables the pushing cycle to be operated step by step by the manual depression of the individual press-button switches. This facility is necessary during the starting-up procedure following a week-end shut-down and for maintenance purposes.

The cycle control panel contains all the switchgear necessary for the operation of the pushing cycle. A series of indicator bulbs come on as the cycle proceeds. These show at a glance the position of the doors and pushers should any breakdown of the cycle occur. The bulbs remain on until the cycle time expires, when they are cancelled ready for re-lighting as the next pushing cycle proceeds.

In addition to the limit switches and ratchet relays provided for cycle operation, three extra limit switches are installed to help avoid damage to the furnace and trays. These three prevent the cycle being operated unless :—

(*a*) The overall height of the newly-loaded tray is below the level of the furnace arches and baffle doors (when opened).

(*b*) The discharge door is fully opened.

(*c*) A free space, at least one tray length, is available on the furnace discharge table.

All rollers, tracks and other metallic furnace parts operating at high temperatures are made in nickel-chromium heat resisting alloys.

Tray Design

Each complete tray measures 36 × 40 in. and is made up from six separate castings, four of which, 18 × 20 in., make up the tray base whilst the other two form the central guide rail and hinge. With the hinge in the longitudinal direction, the articulating effect produced is a useful feature and results in the maintenance of contact between the tray and all three sets of roller rails. This ensures even weight distribution over the whole furnace hearth. The comparatively small size of each casting permits a higher degree of soundness to be achieved which will contribute to long tray life. To date, after more than twelve months' operation, all castings—forty assemblies in all—are in good condition. The trays are made from nickel-chromium heat resisting alloy.

Temperature Control

The temperature control instruments are of Honeywell manufacture, each operates a motorised valve on the main " combustion air " supply line to the burners of each zone. The burners are of the low pressure automatic proportioning type. Air for combustion is passed through these at a pressure of 1 lb./sq. in. The air passes through a venturi throat in the burner body, thus inspirating a proportionate amount of gas from a gas manifold maintained at atmospheric pressure by means of a counterbalanced gas governor. There is one gas manifold complete with governor on each side of the furnace for each zone. A valve is incorporated in each burner for the purpose of setting the gas/air ratio. Once set, this remains constant whether the burner is on full flow or by-pass flow.

TABLE I.—TYPICAL TREATMENTS

Cycle	Treatment	Temperature (° C.) Zone 1	2	3	4	5	Net Load on Each Tray (lb.)	Cycle Time (min.)	Materials Treated	Brinell Hardness Expected (max.)
A	Isothermal Anneal	900	900	620	620	620	700	60	En 352 En 353 En 355	187 207 228
B	Isothermal Anneal	850	850	630	630	630	700	60	En 19 ; En 24 ;	255
C	Normalise	900	900	Burners off ; control set to zero			700	45	En 1A	
D	Normalise	850	850	Burners off ; control set to zero			700	45	En 8	

Typical Treatments

From what has been said previously it will be appreciated that the furnace is capable of dealing with a wide variety of normalising and annealing treatments. Examples of some of the treatment sequences are shown in Table I. Hardness tests on treated parts have established that uniformity is achieved not only throughout the piece, irrespective of any irregularities in size and shape, but also throughout the load. Typical examples of hardness surveys and photomicrographs showing the general structure are given in Fig. 9.

Summary

During more than twelve months operation the furnace has proved itself to be a useful addition to the plant in the Leyland heat treatment shops. Its versatility permits many treatments to be accomplished satisfactorily, but it is for isothermal annealing treatments applied to low-alloy case-hardening steels that it has proved itself to be especially valuable. The isothermal annealing treatments are rendered more efficient by the presence of the isolated centre zone. These treatments achieve consistent uniformity, both in structure and hardness, from charge to charge, and the treated stampings are well suited to the machining techniques in operation. Simultaneously the treatment dissipates residual stresses arising from the stamping operation, thus providing an important contribution to the dimensional stability achieved during subsequent case hardening. A further and final attribute of the equipment is that the construction, automatic control systems, and external tray handling arrangements, all combine to minimise labour requirements.

Acknowledgments

The author wishes to express his thanks to the directors of Leyland Motors, Ltd., for permission to publish this article. He also wishes to thank Mr. C. C. Hodgson, chief metallurgist to the company, for help and advice, and to thank British Furnaces, Ltd., for the provision of Figs. 5 and 8.

Stress-Relieving on Site at Hunterston

Reactor Vessel Successfully Heat Treated

SUCCESSFUL completion of the stress-relieving of the first 70-ft. diameter reactor pressure vessel at Hunterston Nuclear Generating Station, Ayrshire, Scotland, is reported by The General Electric Co., Ltd., of England. The station is being built for the South of Scotland Electricity Board by the G.E.C. and Simon-Carves Atomic Energy Group. The construction of the pressure vessels was sub-contracted out to the Motherwell Bridge & Engineering Co., Ltd., whose contract included the responsibility for the stress-relieving operation. About 1,800 tons (1,830 tonnes) of steel, situated at a mean height of 85 ft. (25·9 m.) above ground level, was heated to a temperature of 550° C., soaked for 12 hours and then allowed to cool slowly. During the process a high degree of control was essential to prevent the temperature difference between any two points in the vessel exceeding a certain specified maximum.

Installed inside the pressure vessel and undergoing stress-relieving at the same time were the inner heat shield, the core-support grid, and the main gas seal between the walls of the inner heat shield and the pressure vessel. Certain portions of the hot and cold gas ducting and the nozzles for the charge/discharge and control-rod standpipes which penetrate the pressure shell were also included. The steel restraint beams for the graphite core were suspended from the inner shell nozzles, and other items treated at the same time were laid on top of the grid cover plate.

Courtesy of the General Electric Co. Ltd. of England

Installing the electric heating strips under the grid of the first reactor at Hunterston prior to stress-relieving. The man is standing on the slotted angle framework used to support the heaters for the bottom crown of the 70-ft. diameter pressure vessel.

Heating System

Design Considerations

The electric heating system used was proposed and designed by the Industrial Advisory Service of the South of Scotland Electricity Board, who acted as consultants for the heating scheme to the Motherwell Bridge & Engineering Co., Ltd., throughout the job.

When setting out to design the heating system for this complex fabricated structure, certain features in connection with the type of heater to be used, the method of heater suspension, and the insulation of the heating system were considered desirable.

Because of the difficulty of achieving uniform heating by natural convection alone, it was felt that radiant heating should be adopted. The heaters needed to be arranged in zones with external means of varying the heat output of the heater groups in each zone. In order to obtain the best possible heat transfer from the heaters to the fabricated structure, it was better that the heaters should not be surrounded by insulation or sheaths: it was therefore decided to employ heaters in the form of alloy strips.

To achieve good electrical insulation characteristics the heater strips would have to be widely spaced from earth and from each other. Considerable expansion of the whole heating system would take place at the high temperatures involved, so that good clearance between live sections was a prerequisite.

The material used for the heater strip needed to have a high resistivity, so that a robust arrangement could be employed, and be sufficiently ductile for ease of forming. A low temperature coefficient of resistance and good resistance to progressive oxidation when hot were also necessary.

Since, from considerations of maximum radiation, bare conductors would have to be used, separate insulators became necessary. These needed to have a high resistivity at high temperatures, to be resistant to mechanical and thermal shock, and to have a high mechanical strength in tension and compression under working conditions.

General Outline of Scheme

The pressure vessel and included components were heated by a series of freely radiating Brightray strips supported by wire links and ceramic insulators. Some strips were mounted circumferentially between the spherical pressure vessel and the cylindrical inner heat shield, while others on the top and bottom crowns followed approximately the curvature of the vessel.

With the system of heater suspension employed, a curtain-like structure of heater elements was built up in the space between the inner heat shield and the pressure vessel. Brightray heater strips were also placed underneath the grid to ensure that this would be adequately heated. Enclosed tubular-type heaters were employed for each of the gas ducts. The method of suspension adopted was extremely flexible, and per-

mitted the switching off of one heater without fear of damaging the suspension of neighbouring heaters.

It was considered necessary to divide the fabricated structure into 40 (including gas ducts) separate heating zones. By choosing suitably dimensioned heating strip it was possible to use 100 ft. (30·5 m.) lengths connected directly across the 240 V. mains. This length of strip was chosen because it was half the circumference of the spherical pressure vessel, enabling the supply to be brought in at one side of the vessel and the neutral connection to be taken out at the other side.

Heaters

Except for the ducts, all heaters were made of Brightray strip, with the strip section slightly reduced for the top crown. Inside each zone the heater strips were connected in groups, each group being supplied from an externally-mounted auto-transformer fitted with voltage ratio adjustment. This allowed a measure of control to be exercised over individual heating groups.

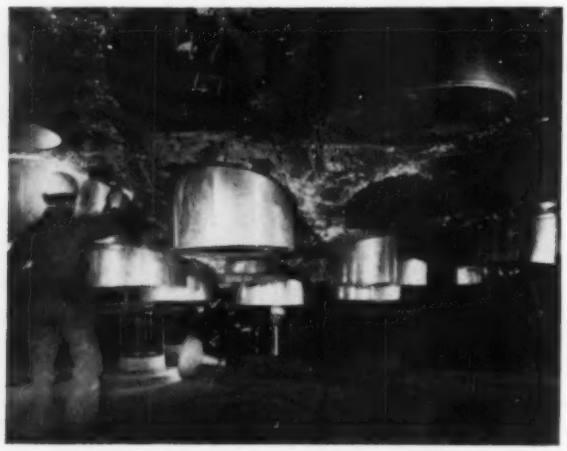
Each duct heater was 8 in. (20·3 cm.) in diameter and 6 ft. (1·83 m.) long, with a rating of 24 kW. at 240 V., and of stainless-steel construction. Two heating units were used in each hot gas duct, and one heating unit was employed in each of the shorter cold gas ducts.

Insulators and Support Links

Although the linkage system between element arrays varied from zone to zone, only one type of ceramic insulator was used throughout the whole installation. All the support links were of Incoloy D.S. wire, which at 800° C. has a tensile strength of 10·5 tons/sq. in. (1,650 kg./sq. cm.). The stress in the most heavily loaded link at this elevated temperature was less than 0·1 tons/sq. in. (15·7 kg./sq. cm.), so that a high mechanical factor of safety was provided. This wire has a melting point of not less than 1,320° C. and a coefficient of expansion of $18{\cdot}5 \times 10^{-6}$/°C.

Thermal Insulation

All external surfaces of the pressure vessel, ducts, and nozzles were insulated to reduce heat losses. In most cases this insulation consisted of two 3 in. thick (76·2 mm.) layers of Rocksil, but in some instances, namely round the duct stubs and skirt, the thickness was increased to 12 in. (30·4 cm.). Aluminium foil was widely used to reduce radiation and so protect the concrete surfaces.



Courtesy of the General Electric Co. Ltd. of England

Rocksil thermal insulation applied to the bottom crown of the first reactor pressure vessel at Hunterston, Scotland. The charge nozzles were insulated individually and then covered by a thin aluminium container as shown.

The inner layer of Rocksil had a density of 9 lb./cu. ft. (0·144 g./cu. cm.) and was backed on each side with a layer of 1 in. mesh (25·4 mm.) galvanized wire netting. The outer layer was of similar construction but its density was 6–7 lb./cu. ft. (0·096–0·112 g./cu. cm.) and a 0·001 in. (0·025 mm.) layer of aluminium foil was interposed between the insulation and the wire mesh on the outer face.

Experimental work had already established that a 12 in. (30·4 cm.) thickness of Rocksil was required on each side of the vessel support skirt to achieve an acceptable temperature gradient down the skirt under reactor operating conditions. Further investigation indicated that this was satisfactory for the stress-relieving operation also. The increase of thickness of insulation on the duct stubs where they passed through the 8 ft. square (2·44 m.) openings in the inner biological concrete shield ensured that the temperature of this concrete did not exceed 150° F. As a further precaution against undesirable increases in the temperature of the concrete, arrangements were made to pass about 300,000 lb. (136,400 kg.) of air per hour through the biological shield cooling system.

Temperature Measurement

Thermocouples

Temperatures were measured at some four hundred points by means of Chromel-Alumel thermocouples. All the internal and external positions for the permanent thermocouples were used and in addition a number of temporary points was selected. The readings from these thermocouples were recorded by two different instrumentation systems described later. Particular attention was paid to the positioning of thermocouples on the pressure-vessel support skirt, gas-duct stubs, and sphere.

It was possible to record the temperature distribution down the support skirt in various planes around its periphery, thus enabling a check to be made on the performance of the thermal pocket at the top of the skirt. The temperature along each gas-duct stub was measured at several points to ensure that no large temperature gradients occurred. In addition, four pairs of thermocouples were connected differentially to record any temperature variation between selected points at the top and bottom of the large irregularly-sectioned forgings at the duct roots. A pair of thermocouples, one connected to the top crown and the other connected to the bottom crown, was arranged to indicate the temperature difference between the two points, thus enabling the controller to regulate the heat input to maintain an even temperature distribution throughout the pressure vessel.

The vessel could be symmetrically divided into four quadrants, and it was fairly reasonable to assume that the heating pattern would be similar in each quadrant. Thus it was decided to connect strip-chart recorders to the thermocouples in one quadrant only, with a few check thermocouples in the other quadrants.

In addition to the thermocouples used for the pressure vessel and its contents, about twenty were placed in the surface of the concrete biological shield at the equator level, on the concrete beams forming the soffit, and in the concrete supporting the reactor skirt, to ensure that the rise in concrete temperature was not excessive. Thermocouples were also used to measure the temperature of the heater strips at various points.

Instrumentation

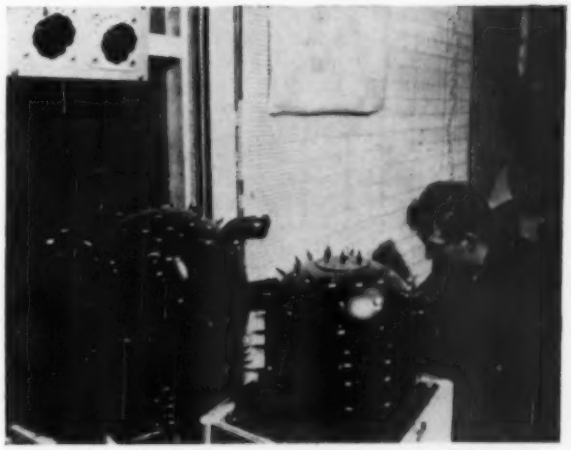
In order to eliminate the fatigue and consequent inaccuracy arising from the continuous logging of large numbers of temperatures by an operator, two special instrumentation and recording systems were employed. Approximately three-quarters (i.e. about three hundred) of the thermocouples were connected to a digital typewriter recording system which presented the temperatures in the form of a printed list, while the remaining quarter were connected to six strip-chart recorders. This procedure was adopted for two reasons. Firstly the strip-chart recorders could be used to control the heating cycle for a limited period in the event of failure of the digital typewriter system (or vice versa), and secondly the strip-chart instruments provided a record which could be interpreted more quickly and easily than that of the digital typewriter.

As readings of the temperatures were taken from the recorders they were plotted in the form of a graph on a specially-constructed peg board in the control room. On this board temperature was plotted horizontally (in 5° C. steps) and the hundred thermocouples were plotted vertically. Thus by plotting the readings of these thermocouples during the stress-relieving operation an overall picture of the heating pattern was presented.

Adjacent to this board were two models, one of the pressure vessel and the other of the inner heat shield resting on the grid. Fixed to the models were small lamps in positions corresponding to those of the hundred thermocouples represented on the peg board. By placing a small plug in a thermocouple position on the board the appropriate lamp on the model lit up. The purpose of this arrangement was to enable the position of a thermocouple in the vessel to be located quickly if it showed that the temperature in that part was differing too widely from the mean temperature of the whole structure. Remedial action could then be taken by reference to electrical control information on the peg board.

Forming part of the peg board were two other display systems. The first showed the power loading of each heater circuit in the pressure vessel and the tapping position of each of the twenty-four auto-transformers; and the second showed the cycling of the tubular duct heaters. The complete peg board and models were designed and constructed by the South of Scotland Electricity Board Industrial Advisory Service.

The equipment for the digital display system was specially developed by G.E.C. and was arranged for either automatic or manual operation. When on automatic operation all the thermocouple readings were sequentially scanned and printed out by an electric typewriter. If required, special observation of particular thermocouples could be achieved by selecting and printing a fewer number of temperatures more frequently. On manual operation, by the use of a push-button, individual thermocouple readings could be selected and logged by the control engineer.



Courtesy of the General Electric Co. Ltd. of England

Two models used to determine the position of a 100 selected thermocouples. The peg board provides a graphic picture of the temperatures at various points inside the pressure vessel.

Four uniselectors having gold-plated contacts each handled one quarter of the three hundred thermocouple circuits. The uniselectors were driven by relays which were electrically interlocked with the indicators and print-out system to control the logging sequence. The output side of each uniselector was connected to an Electroflo type 198 potentiometric indicator scaled to read 1,000° C. The balancing time of the indicator was nominally one second, but if the difference between the two successive temperatures was small, this time was greatly reduced. In order to take advantage of this, balancing detectors were fitted so that print-out was initiated immediately all four indicators were balanced.

Each indicator was also fitted with a Hilger and Watts digitizer having an output in the Watts reflected decimal code. When the four indicators were balanced, the output of each digitizer was decoded in turn by a single decoding unit and passed to the I.B.M. electric typewriter.

Once during a complete scan (i.e. through all four uniselectors), each indicator was connected to a standard reference, corresponding to a reading of 800° C. This provided a means of checking whether the logging installation was functioning correctly. Accuracy of the potentiometric indicators was 0·25% f.s.d. and the accuracy of translation was ± 1 digit. The system was calibrated at 550° C. and a correction card was made to cover other temperatures.

Since the electric typewriter was able to print 10 digits/sec., multi-bank uniselectors capable of switching the inputs of the four indicators simultaneously were employed, the four outputs being printed out sequentially. The print rate was thus 2½ digits/sec.

Additionally the five differential thermocouple readings were registered on a separate chart recorder so that special and continuous observation of them was possible.

Power, Cables and Communications

Power Supplies

Although the South of Scotland Electricity Board made a 4·5 MW. supply available for the stress-relieving, in fact the maximum demand never exceeded 3·6 MW.,

corresponding to 2 kW./ton of metal treated. Power was taken from the main site substation through circuit-breakers to four 1,000 kVA. 11/0·415 kV. three-phase transformers, hired by the South of Scotland Electricity Board for stress-relieving purposes. Each of these transformers supplied six 150 kVA. single-phase auto-transformers, two per phase in parallel, having voltage ratios of ten equal steps. The auto-transformers were also individually switched to provide cycling control should the minimum voltage tapping obtainable prove too high.

Power and Thermocouple Cabling

Because of the high temperature involved, special arrangements were adopted to take the power supplies to the heating elements inside the pressure vessel. Stainless-steel conductor rods were used for the power connection to the heaters, groups of these rods being taken in through the charge nozzles to supply the bottom crown and grid heaters, through cold gas ducts to supply the curtain and through the control-rod nozzles to supply the top-crown heaters. Welded connections were used between all the heater strips and the stainless-steel rods, since it was imperative that no faults should arise at these points when the stress-relieving was in progress.

Mineral-insulated stainless-steel-clad cables were used for all thermocouple leads. These cables were grouped together and brought out through nozzles in the pressure vessel. At suitable points outside the pressure vessel, these cables were terminated in junction boxes from which normal multicore cables were run to eight further junction boxes in the control room. The leads from these boxes were then taken to the temperature-scanning equipment.

Communications

Telephones were installed to link the control room, housing the temperature recording equipment, with the four switching positions. The controller was responsible for co-ordinating the readings from the various heating zones and for issuing the necessary instructions to the switching operators.

Operating Procedure

As there was no previous experience to draw on for controlling the heating rate of vessels of this size and complexity, it was not possible to lay down a set of rules governing the operation. Initially the bottom crown heaters were switched on at their lowest setting, i.e. half load, and held at this level until the heating pattern emerged. The switching instructions were then based on this pattern. It was agreed to limit the rate of temperature rise to less than 5° C./hr. and on this basis it took approximately seven days for the pressure vessel to reach the stress-relieving temperature of 550° C., at which it was soaked for twelve hours. Throughout the whole operation there was not a single heater failure. As would be expected, the overall rate of heating was controlled by that of the bottom crown, because natural convection tended to take the heat away from this part of the sphere. After the soaking period the vessel was left to cool for nine days before removing the thermal insulation. Entry to the vessel was delayed a further two days.

Conclusions

Over the past few weeks a considerable number of tests have been carried out on the fabricated structure to check the success of the stress-relieving. These tests were laid down by Lloyds Register of Shipping (Land Division), with the approval of the U.K.A.E.A., the South of Scotland Electricity Board, and the consultants to the Board, Messrs. Kennedy & Donkin. They included crack-detection tests on 10% of all nozzle welds on the inner heat shield and on the grid, and 100% crack-detection tests of the nozzle welds in the shell and on the gussets. Ultrasonic examination of selected areas on the top and bottom crowns was also carried out.

The absence of any faults in the pressure vessel or its contents indicated that the stress-relieving was entirely successful. Certain minor modifications to the layout of the heating system should result in a reduction in the time taken to treat the second reactor pressure vessel. The use of radiant-heating strips, freely suspended inside the vessel, has been fully justified by the result. An advantage of this system is the ease with which it could be dismantled and to a large extent used again for the second reactor.

Acknowledgments

Acknowledgment is made to The Motherwell Bridge & Engineering Co., Ltd., who were responsible for the construction, installation and performance of a large part of the stress-relieving equipment, and to the Industrial Advisory Service of the South of Scotland Electricity Board, who acted as consultants for the process. Duncan Low, Ltd., of Glasgow, supplied the heaters used in the gas ducts.

Meeting Diary

(*continued from page* 158)

15th November

Institute of Welding, West of Scotland Branch and **Institution of Structural Engineers, Scottish Branch.** "Who Teaches the Science of Welding?" by DR. J. ORR. Institute of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow C.2. 7 p.m.

Society of Chemical Industry, Corrosion Group. A Controversial Evening to ventilate outstanding points of doubt and dispute in corrosion science. Contributors: C. EDELEANU, E. Ll. EVANS, J. E. KAYSER, J. N. WANKLYN. 14 Belgrave Square, London, S.W.1. 6 p.m.

16th November

West of Scotland Iron and Steel Institute. "Marking, Cutting and Testing of Steel." Institute of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow C.2. 6.45 p.m.

20th November

North East Metallurgical Society. "Recent Advances in the Foundry," by A. T. ANDREW. Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough. 7.30 p.m.

Sheffield Metallurgical Association. "Two Years' Experience of Vacuum Degassing," by J. H. FLUX and J. HEWITT. The Engineering Lecture Theatre, The University, St. George's Square, Sheffield. 7.30 p.m. (Joint meeting with the **Sheffield Society of Engineers and Metallurgists**).

21st November

Sheffield Metallurgical Association. "The Extraction and Melting of Some Non-Ferrous Metals," by N. H. JACKSON. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

22nd November

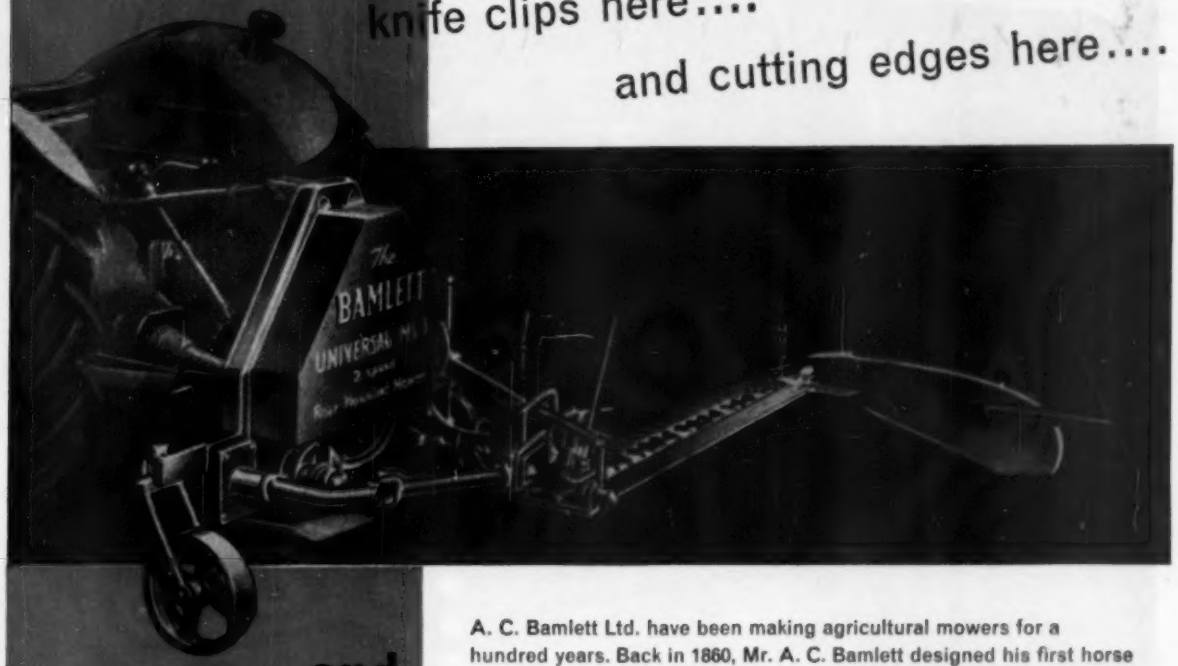
Manchester Metallurgical Society. "Metallurgy of the Rarer Metals," by J. C. CHASTON. Manchester Literary and Philosophical Society, George Street, Manchester. 6.30 p.m.

There's a knife head here....

a connecting pin here....

knife clips here....

and cutting edges here....



and they're all case-hardened in a 'Cassel' salt bath furnace

A. C. Bamlett Ltd. have been making agricultural mowers for a hundred years. Back in 1860, Mr. A. C. Bamlett designed his first horse drawn mower. It is a tribute to his ingenuity that the firm still use the same principle today, when the horse has long since been replaced by the tractor.

In an era of increasing mechanisation in farming, Bamlett's have kept their leading place by their enlightened outlook on manufacturing techniques. The principle may date from 1860—but the methods belong very much to the 1960's.

They became dissatisfied with their method of heat-treatment and, after investigation, decided to instal an I.C.I. 'Cassel' salt bath to help them case-harden those parts of their mowers that were most subject to hard wear.

They case-harden to a depth of .015/.025"—and have found that with the 'Cassel' bath they can easily control this depth, which gives uniform results and longer life to the treated parts.

In addition, their output has doubled for the same labour, and their costs have been reduced.

Bamlett's would certainly agree that

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I.C.I. HEAT-TREATMENT SERVICE

IMPERIAL CHEMICAL INDUSTRIES LTD

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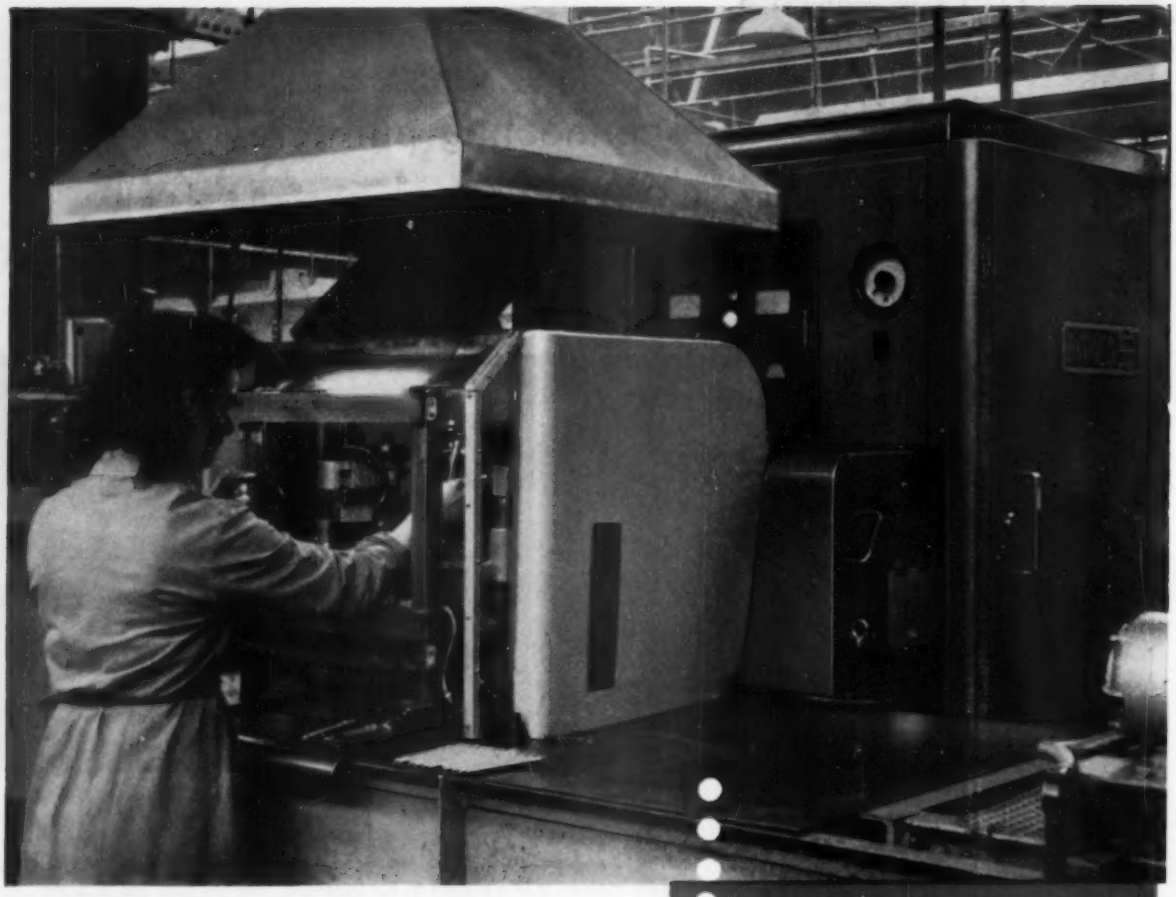
ICI

GENERAL CHEMICALS DIVISION



Wild-Barfield A.H.F. equipment is used by Wolf Electric Tools, Ltd., (manufacturers of the well-known Wolfcub drills etc.), for the hardening and tempering of small gears, shafts and pinions. Many other industrial concerns have found that Wild-Barfield A.H.F. induction heating speeds production, saves space and offers savings all along the line. Our engineers will be glad to supply further details and explain how Wild-Barfield A.H.F. equipment can help you.

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WB 64

NEWS AND ANNOUNCEMENTS

Computer Controlled Oxygen Steel Plant

INTERNATIONAL SYSTEMS CONTROL, LTD., of Wembley, announce that Thompson Ramo Wooldridge Inc. of Los Angeles (which, with the General Electric Co., Ltd., of England is jointly interested in I.S.C., Ltd.) has received an order from the Great Lakes Steel Division of the National Steel Corporation for a computer system to control the world's largest basic oxygen steel furnace plant at Detroit.

The computer will determine the amount of raw materials required and prescribe the amounts and types of additives necessary to produce a given quantity of finished ingots of the right specifications. It then takes care of the furnace process, controlling the heat generated by adjusting the flow rate and duration of the oxygen blow. Besides maintaining a consistant product of top quality this precise control also ensures the minimum consumption of raw materials and oxygen. From the data which the computer automatically records, a close relationship between furnace conditions and finished ingot characteristics can be drawn up, for use in determining the optimum conditions for subsequent batches. At the same time the computer's programme can be automatically revised as more is learnt about the furnace operation.

The whole of the information on this installation will shortly be available for use by International Systems Control, Ltd., in the same way that the details of earlier Thompson Ramo Wooldridge projects in the chemical, oil, nuclear, electric power and other fields are available to the joint company, to be applied to similar plants in the U.K., the E.F.T.A. countries, and the Commonwealth.

Vacuum Technology Symposium

THE Institute of Physics and the Physical Society announces that it will be holding a one day symposium on " Some Aspects of Vacuum Science and Technology," at the Imperial College of Science and Technology, London, on 5th January, 1962. The scope of the symposium will be: (*a*) continuously exhausted bakeable vacuum apparatus for pressures below 10^{-9} mm. of mercury, and (*b*) the controlled deposition of evaporated film. Further details and application forms will be available about the end of October, 1961, from the Administration Assistant, The Institute of Physics and The Physical Society, 47 Belgrave Square, London, S.W.1.

A.E.I. Order for Steelworks

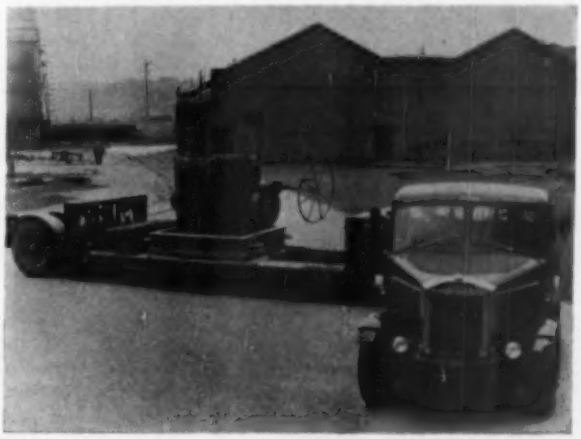
ELECTRICAL equipment valued at £45,000 has been ordered from the motor and control gear division of Associated Electrical Industries, Ltd., by Stewarts and Lloyds, Ltd., of Corby. The equipment is required for the modernisation of a continuous weld mill to increase output of 1¼ in. steel tubing to 750 ft./min. or 4 in. tubing to 320 ft./min. The work will involve the replacement of the present mill saw with a special American type of flying saw which, in turn, calls for more powerful electrical equipment having wide and easily controlled speed variation, together with an electronic device for matching saw performance with that of a selected mill stand.

The flying saw will be driven by a 25 h.p. A.C. mains powered motor, but to facilitate overall operational speed control of the mill, and achieve greater accuracy of pipe length cuttings, direct current will be used to power all seven of the actual mill motors and the saw crank motor. This direct current will be provided by an A.E.I. type Ward-Leonard motor-generator set comprising a 400 h.p. mains powered A.C. synchronous motor driving a 220 kW. D.C. generator with a 40 kW. constant voltage exciter, and a small 10 kW. " booster " generator. Six of the eight 40 h.p., D.C. motors will drive mill stands, one the saw crank, and one the back-end roll when this is in use in conjunction with the preheating of strip. Speed matching of saw performance and a selected mill stand will be by means of a magnestat, or magnetic amplifier, fed by the output of two tachometer generators; differences of output will automatically adjusted by the 10 kW. booster generator.

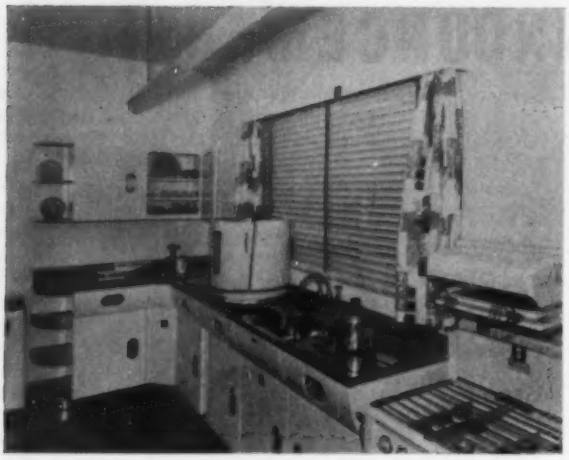
A.E.I. development engineers have also been given the task of investigating the problem of measuring tube length and applying correction signals to increase accuracy and thereby reduce wastage.

Corrosion Science

LARGELY because of the subject's numerous facets, papers on corrosion are published by chemical, metallurgical and engineering journals in many countries; there are also several national publications dealing solely with corrosion and protection topics. Corrosion knowledge has thereby become widely diffused and extremely dilute and in the hope that it will form a link between corrosion scientists all over the world, and will come to



Used for hauling trailers with ladles of molten steel at the East Hecla works of Hadfields, Ltd., Sheffield, this Scammell Highwayman is the first of its kind to be equipped with power-assisted steering. It hauls the ladles from the melting shop to the pouring bay.



Outwardly normal—except for its luxury—this kitchen is unusual in that most of its furnishings and equipment are either wholly or partly made from aluminium. It appeared in a bungalow at the 1961 New Homes Show, and was designed to demonstrate the wide variety of domestic uses for aluminium. The picture shows a Hoovermatic washing machine (just visible at extreme left), aluminium kitchen units by English Rose, aluminium dishwasher by Electrolux, extruded aluminium strip light by the Merchant Adventurers, built-in food mixer with aluminium mincing attachment, aluminium Venetian blind by Quillven, Ltd., and aluminium pressure cooker by Prestige.

provide each of them with a selection of the most interesting papers from the world's corrosion laboratories in concentrated form, Pergamon Press, Ltd., has recently introduced a quarterly publication, *Corrosion Science*.

The new journal, which appears under the auspices of the Corrosion Science Society and the Centre Belge de l'Etude de la Corrosion with the assistance of an international editorial board, will contain original papers, short notes and critical reviews on every aspect of corrosion science. The first issue contains papers on: the development of stress-corrosion cracks in austenitic Cr-Ni steels; the propagation of stress-corrosion cracks in metals; the anodic characteristics of mild steel in dilute aqueous soil electrolytes; the resistivity of various materials to attack by molten salts and metals; and some effects of electrolyte motion during corrosion.

The annual subscription (including postage) is £7 ($20) for libraries, government establishments and research institutions, and £3 10s. ($10) for individuals who write directly to the publisher certifying that the journal is for their personal use.

Plant Engineers' Refresher Course

THE Institution of Plant Engineers announces that the next of its comprehensive refresher courses for works and plant engineers is to be held in Scotland this winter, at the Institution of Engineers & Shipbuilders, Elmbank Crescent, Glasgow. Sponsored by Sir Andrew McCance, F.R.S. (chairman of Colvilles, Ltd., and chairman of the board of governors of the Royal College of Science and Technology), and available to all engineers who wish to take advantage of it, the course comprises eighteen weekly lectures on Wednesday evenings, commencing 1st November.

The fee for the course is four guineas and copies of the syllabus and full particulars may be obtained from the Secretary to the Refresher Course, 39 Elmbank Crescent, Glasgow, C.2. (Telephone: Glasgow Central 5181.)

Magnesium Elektron, Ltd.

WITH the purchase by The British Aluminium Co., Ltd., of the Distillers Co., Ltd.'s 40% shareholding in Magnesium Elektron, Ltd., the last-named company is now a fully-owned subsidiary of British Aluminium. Magnesium Elektron is the sole producer of magnesium metal in this country, and has won international recognition for its successful development of high performance magnesium alloys, its processes being licensed in many countries of the world, including the U.S.A.

Hitherto the metal has been produced by Magnesium Elektron at Clifton Junction, near Manchester, by the electrolysis of the fused chloride, but the present cost of electric power—nearly six times that of 1936—had made this process uneconomic. Plans are in hand for the erection of a plant with a capacity of 5,000 tons per annum at Hopton, near Wirksworth in Derbyshire, to extract magnesium of 99·9% purity from the local dolomite by a thermal process at present operated successfully by Dominion Magnesium, Ltd., of Canada. The completion of the new plant will make the U.K. largely independent of imports from overseas of this strategically important light metal. The dolomite deposits and the plant equipment and layout are such as to permit further expansion to meet increasing demand.

Course on Engineering Materials

A POST-GRADUATE course of thirteen lectures on engineering materials, organised by the Department of Applied Chemistry at the Northampton College of Advanced Technology, St. John Street, London, E.C.1, will be held at the College on Monday evenings, commencing 13th November, 1961. The course will deal with the structure of both metallic and non-metallic materials and its effect on properties, and with the effect on structure of heat and mechanical treatments. The effects on the structure and properties of materials of corrosion, friction, and nuclear radiation will also be discussed.

The fee for the course is three guineas and enrolment may be effected by personal attendance at the college or by application for an enrolment card, which should be completed and returned at least a week before the start of the course.

Foundry Welfare

THE Minister of Labour has used his powers under the Factories Act, 1959, to re-appoint the Joint Standing Committees on Health, Safety and Welfare in Non-Ferrous Foundries, in Steel Foundries, and in Iron Foundries. The function of these three committees, each of which has been appointed for three years, is to advise the Minister on matters affecting the health, safety and welfare of persons employed in the non-ferrous, steel and iron foundries, respectively. The committees replace and continue the work of the joint standing committees on conditions in these three types of foundry, set up by the Chief Inspector of Factories in 1947 (iron), 1952 (steel) and 1953 (non-ferrous).

New Holding Company for B.S.A. Tools

A NEW holding company, B.S.A. Tools Group, Ltd., has been formed for the ten companies previously included in the B.S.A. tools division : all are subsidiaries of the Birmingham Small Arms Co., Ltd. The object of this change is for ease of administration in view of the division's widening activities and expanding volume of business. The board of B.S.A. Tools Group, Ltd., will be MR. E. TURNER (chairman), MR. S. A. ROBERTS (managing director), MR. C. H. ANGELL, MR. E. W. HUNNISETTE, MR. W. H. PEARSE, MR. H. C. W. TRAPMORE, MR. T. N. WOOF ; secretary : MR. M. DUNSTAN-SMITH. Mr. S. A. Roberts will be chairman and managing director of the following subsidiaries : B.S.A. Tools, Ltd., Burton, Griffiths & Co., Ltd., B.S.A. Small Tools, Ltd., B.S.A. Broach Co., Ltd., B. G. Machinery, Ltd., B.S.A. Electrics, Ltd., Precision Alloy Castings (Birmingham), Ltd., and Automation Jigs & Tools, Ltd. MR. E. TURNER, chairman of the parent Birmingham Small Arms Co., Ltd., will be a member of each of these boards and chairman of the Churchill Machine Tool Co., of which Mr. Roberts will be deputy chairman. Mr. Turner will be president of B.S.A. Tools (Canada), Ltd., and Mr. Roberts, vice-president.

The Institute of Welding

THE Institute of Welding autumn meeting, to be held in London from 30th October to 3rd November, 1961, will take the form of a symposium on welding in shipbuilding, covering such aspects as design, materials, yards and construction, welding and cutting, and quality control. On the Wednesday evening the annual dinner of the Institute will be held at the Connaught Rooms, and on Thursday evening, Mr. H. West will deliver his presidential address. Tickets are required for all meetings and functions.

Large Roller Hearth Furnaces

AEI-BIRLEC, LTD., have secured an order for the supply of three roller hearth furnaces to Stewarts and Lloyds, Ltd. for installation at the Corby works. Two of the furnaces are rated at 2,080 kW., to operate at a maximum temperature of 1,000° C., and the other is rated at 1,200 kW. for a maximum temperature of 750° C. Each furnace is capable of an output of 8 tons steel tube per hour at its appropriate operating temperature, the maximum diameter of tube being 6 in. and maximum length 50 ft. The furnaces are adaptable to blue/black annealing, bright annealing, normalising and low temperature treatment. Valued at over £200,000, the plant is of the latest Birlec design and is to be commissioned during 1962.

Aeroplane for Davy-Ashmore Executives

A BEECHCRAFT Queen Air aeroplane has been delivered to Davy-Ashmore, Ltd., by Short Brothers & Harland, Ltd., Beechcraft distributors for the British Isles. The expansion and diversification of Davy-Ashmore group activities has meant—and will increasingly mean—much more travelling for senior officials, both of the parent company and the various operating subsidiaries. Much of this increased travelling is abroad, as a result of the group's intensification of its selling efforts in export markets. The newly-acquired aircraft will be invaluable in maintaining closer contact between the group's manufacturing centres in the United Kingdom and its branches and customers overseas. It will effect considerable savings in valuable travelling time, make it easier for urgent journeys to be arranged at short notice and allow far more flexible itineraries to be planned.

Polarographic Society Meeting

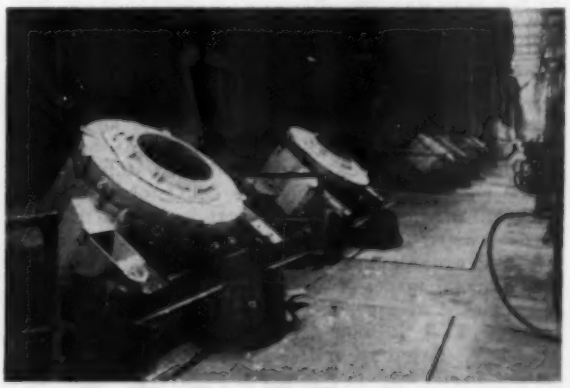
THE September issue of *Metallurgia* included an announcement of a meeting of the Polarographic Society to be held at the School of Pharmacy, Brunswick Square, London W.C.1, on Wednesday, 25th October. The time of the meeting was given as 2.45 p.m., but we understand that this has now been changed to 2.30 p.m.

Personal News

WHEN the four new assistant managing directors of Castrol, Ltd., take office on January 1st, 1962, they will relinquish their present executive appointments and will be succeeded by MR. K. C. MCCARTHY as general manager, Castrol division ; MR. W. F. PHILLIPS and MR. R. LAYET as general managers, overseas division ; MR. E. E. HUGHES as sales manager, Castrol division ; and MR. K. E. SHUREY as group publicity manager. The following further appointments will also take effect on January 1st, 1962 : MR. W. F. FREESTONE as manager, overseas division ; MR. C. E. PARSONS as manager, overseas marine department ; and MR. J. C. EDMUNDS as assistant group publicity manager.

THE George Cohen 600 Group, Ltd. announce that they have appointed MR. P. BONNER to the board of their associate company, T. C. Jones & Co., Ltd., structural engineers of London and Treorchy, South Wales.

MR. D. R. WALKER has been appointed secretary of the Vitreous Enamel Development Council, and the regis-



Six of the eight Morgan basin tilting furnaces supplied by Morganite Crucible, Ltd., Norton, Worcester, to the Wood Lane, Birmingham, works of Aeroplane and Motor Aluminium Castings, Ltd. Each has a capacity of 500 lb. of aluminium and the fast bulk melting, consistent quality control and low melting loss are playing their part in the production of the first gravity die cast aluminium alloy cylinder heads to be made in this country.

tered offices have been transferred from 11, Ironmonger Lane, London, E.C.2, to 28 Welbeck Street, London, W.1. (Hunter 2237). The general manager of the Council is COMMANDER G. CLARKE.

MR. T. BAGNALL, who recently retired as electric furnace melting shop manager from Samuel Fox & Co., Ltd., Sheffield, and who put into operation the first of this country's large arc furnaces, has made his services available exclusively to Birlec-Efco (Melting), Ltd., as from 1st September, 1961. Mr. Bagnall will assist in the design and operation of all equipment manufactured.

DAVY AND UNITED ENGINEERING CO., LTD., a member of the Davy-Ashmore group, has announced that MR. S. BAKER, has been appointed general manager of the machinery division; DR. R. B. SIMS, director in charge of engineering; MR. A. THOMAS, secretary; and MR. G. L. CARSWELL, assistant secretary.

MR. A. C. STURNEY has been elected to the board of the International Nickel Company (Mond), Ltd. He relinquishes his appointment as general manager of publicity, bringing direct to the board his long and outstanding experience in the field of publicity and marketing. Mr. Sturney is succeeded as general manager of publicity by MR. L. F. DENARO, who relinquishes his appointment as assistant to the managing director.

MR. G. D. SAUL has been appointed chief inspector of the United Steel Cos.' Steel Peech & Tozer branch. He succeeds MR. W. M. GLADWIN, who has retired.

MR. GERARD YOUNG, J.P. who was elected as 326th Master Cutler last month is chairman of Tempered Group, Ltd., which consists of six subsidiary companies employing between them some 1,300 people. He joined Tempered Spring Co., now one of the six subsidiaries, in 1930 as management trainee: he was made a director in 1936, managing director in 1942, and became chairman on the death of his father in 1954.

MR. D. PARRY DAVIES has been appointed a director of Mond Nickel (Retirement System) Trustees, Ltd., and is succeeded as comptroller of The International Nickel Company (Mond), Ltd., and Henry Wiggin & Co., Ltd., by MR. L. C. H. VOSS. MR. C. W. R. EDWARDS has been appointed secretary of The International Nickel Company (Mond), Ltd., and Henry Wiggin & Co., Ltd., in succession to MR. E. VAUGHAN, who remains a director of both companies.

SAMUEL FOX & CO., LTD., a subsidiary of The United Steel Cos., Ltd., announce that as a result of the retirement of MR. G. THICKETT, the following staff appointments have been made, effective 1st October: MR. E. HAMPSHIRE succeeds Mr. Thickett as works manager (heavy departments); MR. P. THOMPSON becomes assistant works manager (heavy departments), and will also act as manager of the billet mill; MR. V. G. TYAS is appointed manager of the billet finishing department and MR. T. A. ROGERS, assistant manager, billet bank, MR. R. H. BARROTT, assistant manager, east bank, will be responsible to him; MR. C. GRAY becomes manager of the bar and rod mill, and MR. K. E. FAULKNER, assistant manager (rolling), MR. J. SPENCE, assistant manager (heat treatment and warehouse), and MR. D. R. STONE, assistant manager (planning and supplies) will be responsible to Mr. Gray.

THREE new board appointments have been announced by the Marshall Refractories group of companies: MR. J. R. GLEDHILL who became secretary at the time of the public issue of the company's shares in 1959, has been appointed to the board of Thomas Marshall & Co. (Loxley), Ltd.; MR. A. H. THOMPSON, who joined the group in 1949, becoming production manager at Wrexham Works in 1959 and later works manager, and who since 1960 has been responsible for plant and engineering developments, has also been appointed to the board of Thomas Marshall & Co. (Loxley), Ltd.; and MR. D. GREGORY, who has been works engineer at Storrs Bridge Works, Loxley since 1951 and mines engineer for the group, has been appointed managing director of Ffrith Fireclay Co., Ltd.

MR. C. M. STOCH, assistant director of the British Steel Castings Research Association, Sheffield, has been nominated to deliver the exchange lecture on "The Efficient Use of Oxygen in Steelmaking in British Foundries" to the Technical and Operating Conference of the Steel Founders' Society of America, to be held in Cleveland, Ohio, in November, 1961. In addition, Mr. Stoch will give a summary of the Association's work on the ultrasonic inspection of steel castings. While in the U.S.A., Mr. Stoch will visit a number of steel foundries and research establishments.

MR. T. LEWIS has been appointed a director of Staveley Industries, Ltd. He is chairman of H.P. Sauce, Ltd., and deputy chairman of Wellington Tube Holdings, Ltd. Upon his appointment to the parent company board, Mr. Lewis relinquishes directorships of two Staveley group companies, Bradley & Foster, Ltd., and the Birmingham Chemical Co., Ltd.

Obituary

WE regret to record the death on 22nd September, 1961, of DR. T. P. COLCLOUGH, C.B.E., technical adviser to the British Iron and Steel Federation. Dr. Colclough who was 76, was educated at Manchester and Sheffield Universities and entered the steel industry in 1916. Following a period under Dr. W. H. Hatfield at the Brown-Firth Research Laboratories, he was appointed chief chemist at the Park Gate Iron & Steel Co., Ltd., in 1920, later becoming chief metallurgist, open hearth manager and technical officer. In 1929 he was appointed technical director of H. G. Brassert & Co., Ltd. and was closely connected with the planning of the steelworks at Corby and Ebbw Vale, and with the installation of the first continuous strip mill in South Wales.

From 1942 to 1945 Dr. Colclough acted as technical adviser to the Iron and Steel Control of the Ministry of Supply, and from 1945 onwards he was technical adviser to the British Iron and Steel Federation. At various times he acted as technical adviser to the Control Commission in Germany, and to Iscon, the consortium responsible for building the Durgapur steelworks, and was a member of the Royal Commission on the steel industry of Southern Rhodesia: on behalf of the Federation he led missions to Russia, Poland and Jugoslavia. Interested in the work of the British Iron and Steel Research Association from its inception, he became a council member in 1950.

Dr. Colclough was honoured by the King with the bestowal upon him of a C.B.E., and held the highest award of the Iron and Steel Institute—the Bessemer Gold Medal. In May last, he was appointed an honorary vice-president of the Institute.

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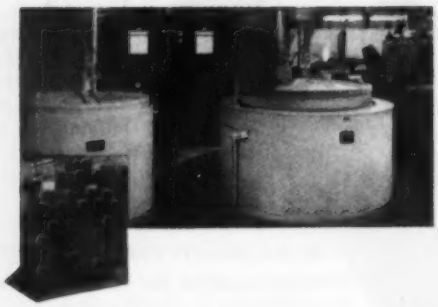

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WE are indebted to the Jaguar Company for the above photographs of the new Model E and part of their Homocarb furnace installation. Homocarb with its twin advantages of forced circulation and exact temperature/time control has won world-wide recognition as will be seen from the following list of some important users.

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RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

Thermal Vortex Burner

THERMAL Vortex burners (licensee : Gibbons Brothers, Ltd., Dudley, Worcs.) are now being manufactured in this country by Thermic Equipment & Engineering Co., Ltd., Preston. Based upon a Lummus Co. design, they operate upon a wide range of residual fuels and waste products including 3,500 sec. and light oils, asphalts, residuum, acid sludges, solvents, and any gas. Changing over fuel without shutting down or simultaneous firing of oil and gas is possible. Heat release rates vary from 1,000,000 B.T.U./hr./cu. ft. on heavy oils to 3,000,000 B.T.U./hr./cu. ft. on gas or light oils compared with the conventional burners' 50,000-400,000 B.T.U./hr./cu.ft. Eight standard models are available, ranging in capacity from 1,300,000 to 48,000,000 B.T.U./hr., with turndown varying between 3 : 1 and 6 : 1 depending upon fuel.

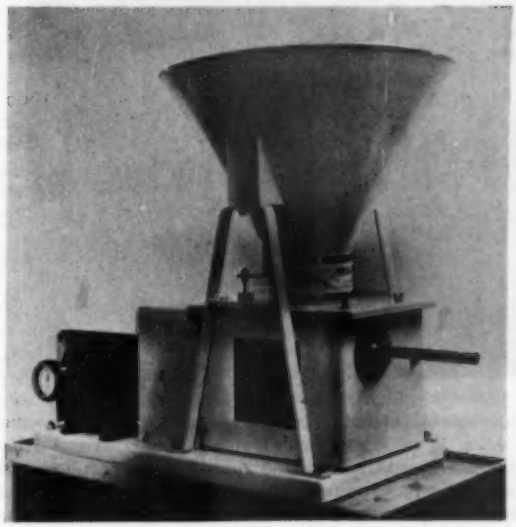
Essentially the Vortex burner consists of an air swirl-vane assembly, burner barrel, controls and refractory lined combustion chamber. Combustion is efficient, compact, rapid and clean, about 80% occurring within the burner, resulting in a very short, whirling, hot (1,650° C.) flame extending only a foot or two from its mouth : thus no external combustion chamber or furnace is required. Conventional fuel and air pressures are used (140 p.s.i.g. oil ; less than 1 p.s.i.g. air) and normal use requires 5% excess air, but the burner is capable of accepting between 70% and 300% of stoichiometric air without resultant soot or flame failure. Ignition is by gas-electric pilot burner and there is provision for flame failure equipment.

The burner's short flame length and high flame velocity (i.e. about 100 ft./sec.) improve convection heat transfer and stir up furnace gases making it particularly useful for oil stills and packaged direct fired air heaters. Designed to complement the burner, the air heaters are extremely compact and incorporate no refractory lining. These economical characteristics are directly attributable to the burner's high heat release rate. The wide range of fuels makes waste incineration easy, again in packaged units. Other applications include inert gas generators and submerged combustion evaporators.

Thermic Equipment & Engineering Co., Ltd., Preston, Lancs.

Volumetric Feeder for Dry Materials

THE Vibra screw feeder, a patented volumetric feeder made under licence from Vibra Screw, Inc., Clifton, N.J., U.S.A., provides industry with a new precision method of metering dry materials into process. It incorporates a screw mounted on a vibrator in such a way that the screw, screw trough, screw bearings and discharge tube vibrate as one assembly while the screw rotates. Feed rates are proportional to the speed of rotation of the screw and are infinitely variable over a range of approximately 50 : 1. The standard range of Vibra screw feeders consists of ten graduated sizes having screws ranging from ¼ in. to 4 in. diameter and



providing feed rates ranging from a few ounces to tons per hour.

The vibratory action of the feeder overcomes sticking, bridging and flooding, and a constant level of material is maintained over the screw to eliminate feed rate fluctuations. The controlled vibration to which the material is subjected also contributes to the exceptional accuracy of the Vibra screw feeder by eliminating aeration and ensuring constant density of the material before it flows into and through the screw and discharge tube. Feed rates are thus kept remarkably uniform from minute to minute and second to second at any speed. With most materials deviations are kept to within ± 1 to 2% minute to minute.

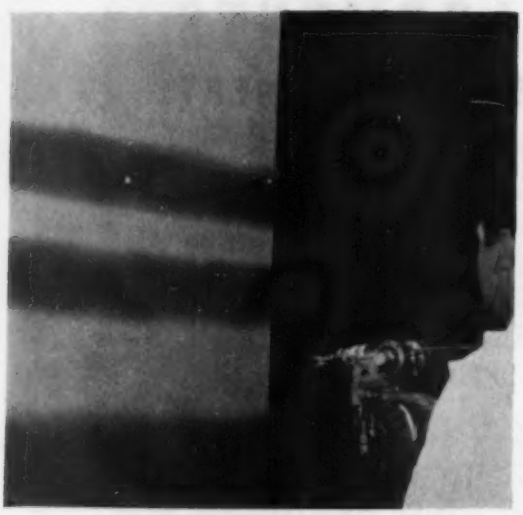
The Vibra screw feeder is said to handle fine powders, flakes and pellets without degradation taking place, and delicate crystalline materials can also be handled without breaking down.

The standard machine construction is mild steel with the screw and discharge tube of stainless steel, but aluminium and plastic finishes can also be supplied to meet specific chemical and other requirements.

Simon Handling Engineers, Ltd., Cheadle Heath, Cheshire.

Aid to Metal Spraying

THE use of metal spraying pistols having a high throughput of metal create new problems in the spraying technique. Pistols now available are capable of spraying zinc at the rate of 60 lb. and more, per hour, and aluminium at equivalent coverage rates. At such high delivery it is of great importance that the metal is applied with the utmost economy. For this reason Metallisation, Ltd., after looking closely into this problem, have produced an auxiliary spreader nozzle for attachment to their Mark 33 metal spraying pistol.



This special attachment will spread the spray stream from a $\frac{3}{16}$ in. diameter wire to an effective width of 3 in. at normal spraying distance. In extended trials the nozzle has proved of considerable advantage when coating large surface areas. The use of high throughput pistols for the spraying of small or complicated shapes is not recommended since the most economical and effective metal spraying depends largely upon selection of the most suitable size of wire.

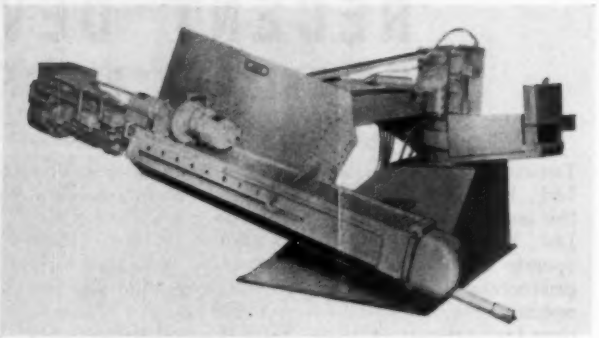
Modern pistols such as the Mark 33 are capable of using wires varying in diameter from 1 mm. to $\frac{3}{16}$ in., so that the selection of wire demands only the change of a nozzle. The new spreader attachment has an additional feature in that it may be switched on and off independently of the pistol. This is effected by means of a small tap situated at the base of the pistol. The illustration shows the coating deposited by one sweep of the gun under normal conditions, compared below with a deposit applied by the spreader nozzle. This auxiliary nozzle adds very little weight to the pistols and may be fitted in a few minutes.

Metallisation, Ltd., Pear Tree Lane, Dudley, Worcs.

Blast Furnace Drill

STUDIES at U.S. steelworks and consultations with blast furnace superintendents led engineers of Joy Manufacturing Co., Pittsburgh, to the conclusion that an electric drill of the rotary type offers a number of advantages over the conventional equipment for tapping blast furnaces. As a result the Joy BFD blast furnace drill has been developed, and is in operation in the United States and France.

Remotely controlled and push-button operated, the Joy BFD requires only one man to drill the iron notch, including penetration of the skull. The operator can be stationed safely in the pulpit area in which the clay gun controls are situated. A steady sweeping motion, without vibration, automatically positions the drill for an accurate tap hole and the powerful rotary action easily penetrates carbonaceous materials. Drill rotation is 300 r.p.m. and forward drilling speed is 4 ft./min.



Clogging, stalling and lunging through weak areas is avoided and the drill rapidly penetrates the skull. Oxygen lancing is unnecessary and the clay and skull are not damaged or vibrated during drilling. The operator has over-riding control at all times, though normally drilling operations are automatic, using limit switches to initiate each phase of the operation.

The drill retracts at 100–150 ft./min., preventing damage to rod or bit, and automatically swings away from the drilling position. Air at 80 lb./sq. in., directed through the hollow drill rod, cleans cuttings from the hole, cools the drill bit and also holds back metal flow. Sparks blown back from the tap hole signal the operator when to retract.

Individual electric motors operate drill swing, drill rotation, forward motion, and retraction. The clean design makes the BFD easy to service and maintain. Each motor is easily accessible and is fitted with external grease leads for quick maintenance. Feed lengths are 6 to 12 ft. Bits can be made by the furnace maintenance department and re-sharpened for repeated use.

Joy-Sullivan, Ltd., 7, Harley Street, London, W.1.

Oscillating Hotplate

THE simultaneous heating and stirring of liquids at a constant temperature for analytical and preparative work in industrial, educational, and medical research and control laboratories can now be achieved quickly by the use of the Griffin oscillating hotplate, which accommodates twenty-eight 250 ml. or eighteen 400 ml. beakers, and oscillates in a circular orbit of $\frac{1}{4}$ in. 216 times a minute, an amplitude and frequency of motion which are optimum for general use. Powdered solids can be prevented from settling and dissolve more rapidly in solvents, while immiscible liquids are kept in intimate contact with each other and can react at a reasonable speed. Spattering is eliminated in the evaporation of neutral and acid solutions, and partially with alkaline solutions. Digestions and precipitations are accelerated, and precipitates are improved.

The hotplate is heated by two steel-sheathed heating elements cast in the shape of an extended S. This construction results in an even temperature over the plate surface. The heating is governed by a Simmerstat regulator which permits a range of hotplate surface temperatures suitable for most heating operations in general analysis up to a temperature of 350° C. (650° F.). The hotplate rating is 2,000 W. at 240 V. The oscillator

is driven by a gear-reduced motor with tropicalised winding and an eccentric driving shaft for moving the hotplate. The motor is set in a cast iron base and stands on rubber feet. The weight of the base and the friction between the rubber feet and the bench top prevents creeping.

Griffin & George, Ltd., Ealing Road, Alperton, Wembley, Middlesex.

Wire Galvanising Process

A VALUABLE new process for galvanising steel wire has been introduced to this country by AEI-Birlec, Ltd., the furnace manufacturing organisation of Associated Electrical Industries, Ltd. Originally developed in France, the new process offers both economic and technical advantages over the conventional sequence of annealing, pickling, fluxing and dipping. Essentially, the Birlec process eliminates the pickling stage: instead, the wire is annealed in such a way as to permit its direct entry to the zinc bath at correct temperature, thus greatly reducing the heat input needed to keep the bath hot. Besides the cost savings implicit in this simplification of the process, the running speed of the wire can be much higher than with the older method, thus giving greater production from a given floor space.

Among the claims made for the new process are: it provides a much improved zinc coating on the wire with virtually no intermediate layer of zinc-iron alloy; wire galvanised by the process will withstand re-drawing or other severe forms of working which would cause flaking of a conventionally produced coating; the quality of the product is not only high but consistent; and both the thickness of coating and the hardness of the wire can be controlled to suit a range of specifications.

The first Birlec plant to operate this process is at present under construction: it will handle approximately 1½ tons of wire per hour. Two similar installations have already been ordered for an overseas plant and it is believed that a large section of the wire industry could benefit from the new process.

AEI-Birlec, Ltd., Tyburn Road, Erdington, Birmingham 24.

Zone-Refined Tellurium

JOHNSON MATTHEY announce that they are now producing zone-refined tellurium of high purity. The total metallic impurity content, excluding selenium, is less than 5 p.p.m., and is normally in the region of 1 p.p.m. The selenium content does not exceed 5 p.p.m. Johnson Matthey tellurium is supplied as half-round bar approximately 1 in. × ½ in.

Johnson, Matthey & Co., Ltd., 73-83 *Hatton Garden, London, E.C.*1.

Phosphating Process

THE Paints Division of I.C.I. has developed and introduced Kephos*, a non-aqueous phosphating process which it is claimed, dispenses with rinsing and tank-heating, forms no sludge in the processing tank, and produces a sealed phosphate coating. The phosphate coating enhances paint adhesion and resistance to rust creep in the same way as conventionally produced zinc or iron phosphate coatings. The improvement in the corrosion resistance of paint systems is said to be quite outstanding and the possibility of work being contaminated by water-borne impurities is eliminated.

Kephos contains a sealer which is sufficiently corrosion resistant to protect work during transport or temporary exterior storage for up to a week, or indoor storage up to six months. Under normal production conditions, work can be welded through the Kephos film. This enables items to be treated before fabrication, so that shrouded areas such as interior box sections receive some protection. Kephos is not confined to dipping: it may be applied by brush, roller, spray or flow-coating, the most suitable method depending entirely on the characteristics and number of the articles to be treated.

Kephos can be used to supplement existing phosphating facilities when an article is too large for the plant or an abnormal volume of work requires processing. For regular use, its higher chemical cost is offset by the compactness and simplicity of plant requirements and the saving in heating and plant maintenance costs, particularly for the manufacturer of a small volume of high quality production. The ideal system is to degrease all work on arrival and apply Kephos before it is put in store; it is thus simultaneously protected and phosphated during storage and subsequent assembly, requiring only the removal of surface dirt to prepare it for painting.

*Imperial Chemical Industries, Ltd., Millbank, London, S.W.*1.

* Patents pending.

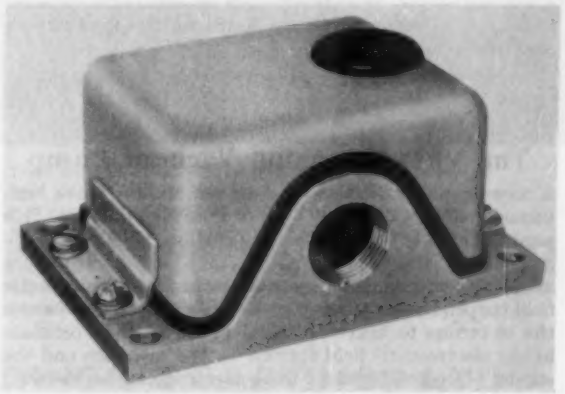
Refrigerator

LEC REFRIGERATION are now producing at a comparatively low cost a refrigerator designed to meet the requirements of industrial laboratories, universities, technical colleges, etc.; in fact any users who require temperatures that can be pulled down to — 100° F. in an hour and maintained. Fitted with indicating thermostat, on/off switch and indicating light, the new model has internal dimensions of 10 × 10 × 10 in. and external dimensions of 21 × 21 × 36 in. high. The tank will hold several gallons of liquid which can be pumped around secondary circuits, thereby providing a flexible cold source.

Lec Refrigeration, Ltd., Bognor Regis, Sussex.

Machinery Protection

THE Vibraswitch is a vibration-sensitive device that protects rotating and reciprocating machinery from



extensive damage resulting from mechanical malfunction. When the vibration level of a Vibraswitch-protected machine exceeds normal by a pre-selected amount, an internal switch closes, actuating either an audible warning system or a shutdown circuit before costly damage occurs. Failing bearings, broken blades and similar malfunctions cause increased out-of-balance or high frequency vibration detectable with the Vibraswitch. This device is available with or without electrical re-set and hold-on coils and can be supplied in water-tight or explosion-proof housings.

Electro Methods, Ltd., Caxton Way, Stevenage, Herts.

Laboratory Potentiostat

THE Wenking potentiostat, now being marketed in the U.K. by Shandon Scientific, maintains a constant potential difference between a test piece and the electrolyte in which it is immersed, irrespective of changes in physical or chemical conditions or changes in the supply current. If the desired constant potential difference is applied between the test electrode and an inert platinum standard electrode, the current flowing through the latter alters its potential relative to the electrolyte, and there results an equal and opposite change in potential of the test electrode. This effect can be obviated by having a third, reference, electrode, e.g. a saturated calomel electrode, through which negligible current passes. Any variation in the test electrode potential is compared with the pre-selected reference electrode potential; the difference (error-voltage) is amplified and applied to the D.C. output to correct the test electrode potential.

Like the Shandon potentiostats Mk. I and Mk. II, the Wenking instrument is basically similar to the original design by Roberts (*Brit. J. App. Phys.*, 1954, **5**, 351) in which both input and output stages of the closed loop feedback system are built round pentodes in push-pull arrangement. The progress in design can be judged from the fact that four valves of the Roberts circuit have been replaced by thirteen valves and six transistors. The use of printed circuits, the careful selection of components, and the final testing of each potentiostat for conformity with rigid specifications, all combine to produce an instrument which, it is claimed, can meet the most exacting research requirements. Over two hundred of these instruments are in use in Europe and America.

The instrument is designed for operation on a 200–240 V., 50 c/s. A.C. supply, and has a power consumption of 150 W. Instrument stabilisation is sufficient to cope with short-term mains voltage fluctuations over the range + 10% to − 15%.

Shandon Scientific Co., Ltd., 6 Cromwell Place, London, S.W.7.

The VPP-5 Penning Vacuum Pump

A NEW addition to the wide range of Mullard ultra high vacuum devices is the VPP-5 Penning pump. This pump, which is continuous in operation, is based on the principle of the Penning gauge, in which electrons are made to oscillate between cold cathodes. A magnetic field perpendicular to the direction of electron flow causes the electrons to traverse spiral paths as they oscillate in the electrostatic field formed by the cathodes and the anode. Ions produced by these electrons are accelerated to the cathodes and liberate more electrons, the combined action being self-supporting.

The VPP-5 pump comprises many Penning electrode units in parallel using common titanium cathodes on each side of a nest of anodes. During operation, the titanium sputters from the cathode on to the anodes, forming fresh surfaces which getter very actively. The life of the pump is dependent on the amount of titanium available at the cathode for sputtering, and is estimated to be 10,000 hours at a pressure of 10^{-6} torr.

The pumping action of the VPP-5 will begin at a pressure of 5×10^{-2} torr and continue until a pressure as low as 10^{-11} torr is reached. Over this range the pumping speed for air is 5 litres per second.

The VPP-5 is contained in a stainless steel case with a metal lead-in consisting of a ceramic seal. Each pump is supplied with its own magnet, which can be removed during bake-out. The pump is connected to a vacuum system by means of a flange and a demountable metal seal. The seal has a $\frac{3}{4}$ in. orifice and can be baked to a maximum temperature of 500° C. The maximum operating temperature is 250° C. Power requirements include an open circuit voltage of 3·0 kV. and a maximum load current of 300 mA.

Mullard, Ltd., Mullard House, Torrington Place, London, W.C.1.

Pultac No. 2

THIS new Pyrene development provides a tough easily removable film which acts as a barrier between overspray paint and the walls of paint spray booths. It can be applied to any surface normally employed in the construction of paint spray booths—steel, aluminium, galvanised iron, vitreous enamel, glass and tiles—and where ferrous metal is concerned, Pultac will also protect against rust. Among the advantages claimed for Pultac 2 are: easy and economical in use, extremely high film strength, resistance to normal overspray thinners as well as paint, resistance to water and water emulsion paints, simplified maintenance and marked saving in labour costs, reduced fire risks in booths by the successful trapping of overspray paint. Application of Pultac is by spraying on to surfaces free from loose material (including rust) and old oversprayed paint. The coating dries out very quickly after application and is resistant to paint overspray almost immediately.

The Pyrene Co., Ltd., Metal Finishing Division, Great West Road, Brentford, Middlesex.

Beryllia-Free Beryllium Copper

JOHNSON MATTHEY announce that in future all Mallory 73 beryllium copper strip up to 0·025 in. thick will be supplied with beryllia-free surfaces. This will reduce tool wear without affecting the mechanical properties of the alloy. Undue tool wear is attributable to the presence of beryllia, a hard and abrasive oxide of beryllium that is formed during the solution heat treatment of the alloy. The oxide is colourless and is not removed by normal cleaning or pickling methods, so that it is often present on material that appears to have a good surface finish. A new process developed by Johnson Matthey completely removes beryllia, and there is no extra charge.

Johnson, Matthey & Co., Ltd., 73-83 Hatton Garden, London, E.C.1.

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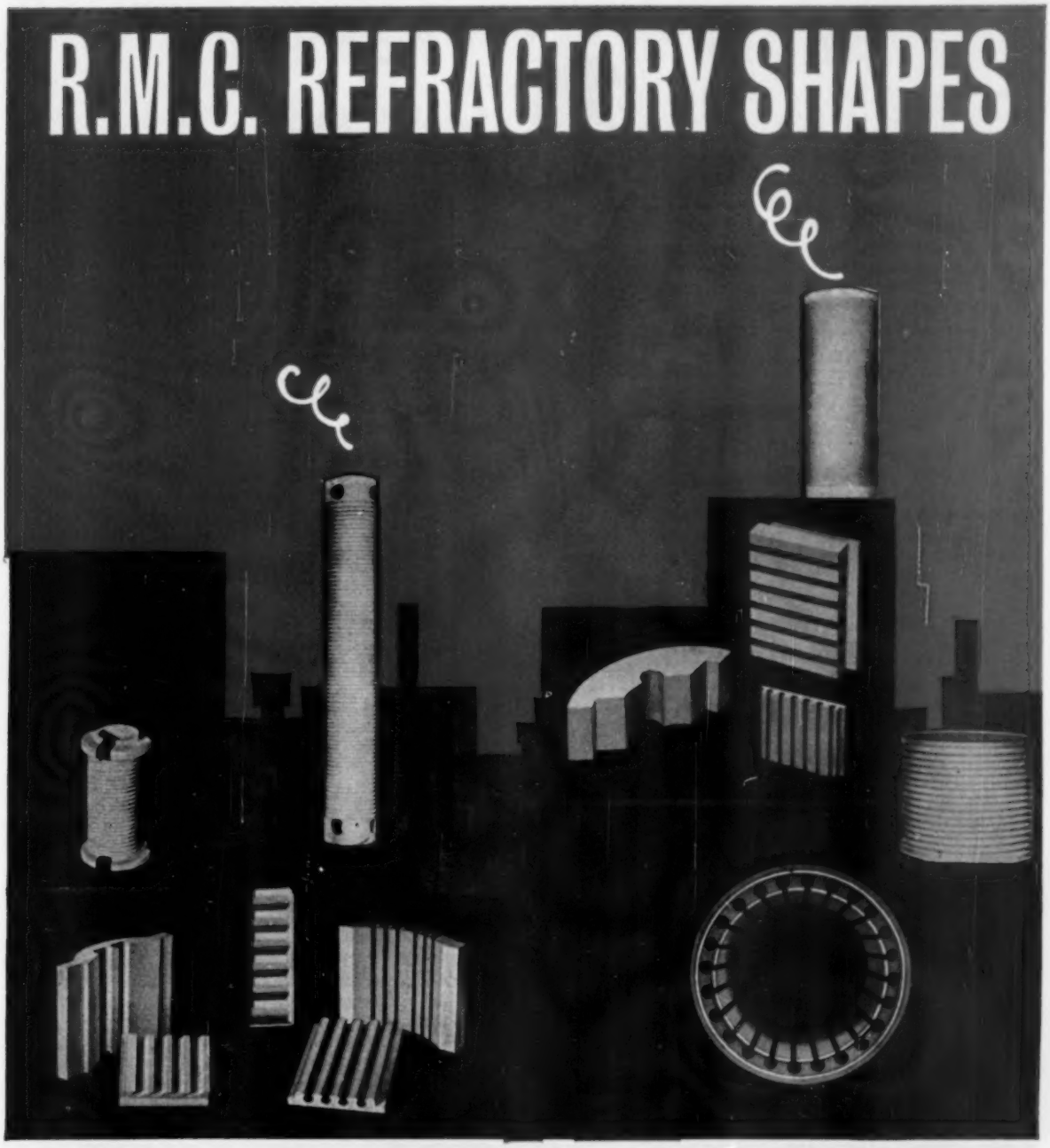

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W.B. 101

CURRENT LITERATURE

Trade Publications

COMPLETING the series of catalogues published in the last few months dealing specifically with the Keith Blackman Tornado range of blowers and exhausters for pressures varying between 1·0 and 52·0 in. static w.g., is the newly issued publication No. 56 on turbo multi-stage blowers. These are produced with from two to seven stages in sizes from 18 to 42 in. and provide a steady, non-pulsating air supply up to a blower pressure of approximately 7½ lb./sq. in. or an exhauster suction of up to 5 lb./sq. in. Applications include supercharging, gas boosting, pneumatic conveying, aeration, exhausting and furnace blowing for such various industrial process plants as steel convertors, board and paper making, coal washing, acid, chemical and carbon black production.

A NEW differential pressure gauge is described in Bulletin E10, available from Pall Corporation, Glen Cove, New York. The bulletin contains specifications, drawings and ordering information. The gauge it describes is a leak-proof model operating by a magnetic coupling. It is designed for indicating up to 60 p.s.i.d. in systems up to 3,000 p.s.i.

THE magnetic oxygen meters described in the Cambridge Instrument Company's List 281/2 have been developed for the determination of oxygen concentrations using methods based on the high paramagnetic susceptibility of the gas. The fact that all other common industrial gases, with the exception of nitric oxide, are diamagnetic enables accurate oxygen analysis to be carried out. Two types of instrument are available, the filament type and the annulus type. The latter is to be recommended particularly for oxygen estimations where more than 1% hydrogen or helium is present, or in applications where a higher speed of response is desirable. It is however affected by carbon dioxide and must be level when used. On the other hand, the filament type detector is comparatively insensitive to carbon dioxide and is more suited to conditions associated with change of level, such as on sea-going vessels.

PARKERISING is a two-stage rustproofing process applied by immersion, the first stage converting the ferrous metal surface into a non-metallic crystalline phosphate coating which is integral with the base metal, and the second impregnating the highly absorbent film with a suitable organic finishing medium to provide a good corrosion resistant surface. A leaflet describing the process—available from the Metal Finishing Division, The Pyrene Co., Ltd., Great West Road, Brentford, Middlesex—lists the range of processes and the special finishes that may be applied at the second stage.

THE improvement of cupola efficiency by adding Brix 100 to the charge is discussed in an article in *Foseco Foundry Practice* No. 148. Brix 100 acts as an "activating" additive to limestone in the charge and among the advantages claimed are higher tapping temperatures, more rapid melting, a lessened tendency for bridging and the formation of slag curtains over the tuyeres, and a reduction in the amount of limestone used. A further feature deals with the effect of the grain size of core sand on corebinder requirements, and the usual extract from the technical service department's "case book" puts forward a solution to the problem of a shrinkage defect in an aluminium alloy gravity die casting.

A NEW booklet entitled "Metal Powders" outlines the range of metal powders now available from Powder Metallurgy, Ltd., the sales organisation for the non-ferrous metal powders manufactured by F. W. Berk & Co., Ltd. The company also handles the sales in Britain of ferrous metal powders produced by atomising techniques developed by F. W. Berk and licensed to the Höganäs organisation in Sweden, Hoeganaes Sponge Iron Corporation in America, and B.S.A. Metal Powders Ltd., in Britain. In addition, the company acts as the sole representative in Britain for sponge iron powders manufactured by Höganäs-Billesholms AB in Sweden. To meet the requirements of new applications, both experimental and in production, ferrous and non-ferrous metal powders are now available in a very large number of grades, many of which can be varied to meet the requirements of the customer. The booklet is available free of charge from Powder Metallurgy Ltd., Berk House, 8 Baker Street, London, W.1.

WE have recently received from Magnesium Elektron, Ltd., Clifton Junction, Manchester, two publications concerned with magnesium alloys. The first of these, dealing with protection and surface treatment, stresses that the alloys are very stable in normal atmospheres and can be used quite as freely as mild steel. When magnesium alloys are used in contact with other materials in humid conditions and when corrosive substances are present, some form of protection is necessary. The booklet details methods for the production and repair of chromate and other protective films. The second M.E.L. publication is a revised edition of the company's "Magnesium Data Book." This contains tables and graphs presenting the mechanical and physical properties of magnesium and its alloys at room and elevated temperatures. In the case of certain properties, figures are also given for other commonly used metals.

A LEAFLET issued by Radiovision Parent, Ltd., Stanhope Works, High Patch, London S.W.7, illustrates equipment for the application of photo-electric controls to such diverse tasks as flame failure detection, batch counting, weld timing and smoke density indication. Also illustrated are centralised control panels which many manufacturers have found to lead to increased efficiency.

WITH a view to providing a general description of the company's historical background, manufacturing facilities and range of products, Thos. Firth & John Brown, Ltd., have issued a booklet entitled "Firth Brown Works and Products." John Brown commenced business on his own account in 1837 and the firm of Thos. Firth & Sons was founded some five years later. It was not until 1930, however, that the amalgamation to form Thos. Firth & John Brown, Ltd., took place, although the Brown-Firth Research Laboratories had been founded in 1908. The booklet presents an illustrated account of the steelmaking and hot working facilities—the latter

ranging from 8 in. bar mills to a 6,000 ton forging press—and the corresponding heat treatment and heavy engineering shops. Reference is also made to facilities for ring and tyre production, forged roll production, casting production, and the nitriding of machined components.

THE Birlec JFC electrically heated furnaces are scaled-down versions of the Birlec range of VFC forced air circulation furnaces, having work baskets 10 in. in diameter and either 10 in. or 20 in. deep. They are general purpose batch type furnaces of vertical cylindrical design, the charge being heated by high velocity air flow. Designed for heat treatment at temperatures up to 700° C., they are supplied as packaged units ready for connection to the power supply. A new leaflet issued by AEI-Birlec, Ltd., features a detailed specification of the Mark II, which has been developed from a long line of successful JFC furnaces and which incorporates features proved by many years of operating experience.

THE latest publication of Combustion Chemicals, Ltd., 33 Dorset Square, London, N.W.1 is Test Data Booklet 250/61, which gives typical results from the use of Desulfurol fuel treatment in furnace, oven and kiln operation. This follows the recent publication of the companion booklet (400/61) covering boiler application and shows the beneficial effects of additions to the fuel oil to the extent of one part in a thousand on such problems as burner coking, sulphur fumes, and sulphur contamination of the product.

OXYGEN analysis equipment is the subject of specification sheet SSO16 issued recently by George Kent, Ltd. The Kent oxygen analyser is based on the paramagnetic property of oxygen and the dependence of it on temperature. Kent can engineer the complete measuring system including gas-sampling equipment, gas analyser, measuring instruments, etc., and details of the equipment available are given in the leaflet.

A NEW leaflet entitled " Industrial Ovens and Filtration Equipment " has been issued by Controlled Heat and Air, Ltd., of Smethwick, makers of industrial ovens covering the whole field of stoving, drying, low temperature heat treatment, etc., up to a maximum temperature of 450° C. Among the applications illustrated in the new publication are tin printing, core and mould drying, varnish drying and baking and roll preheating, on the oven side, and wet dust collection and air cleaning in a vitreous enamelling plant on the filtration side.

A LEAFLET issued recently by the general chemicals division of Imperial Chemical Industries, Ltd., gives details of a new addition to the division's range of degreasing plant. The Type H unit is a standard I.C.I. degreasing plant, arranged for any of the normal forms of heating, to which has been fitted a superstructure carrying a built-in lift to give either semi-automatic or fully automatic working. It is designed for the economical handling of metal parts that can be degreased by a single immersion in trichlorethylene vapour (with or without a wash of clean distillate) or in clean boiling trichlorethylene, provided that they are free-draining as loaded in the basket.

IN addition to manufacturing and supplying all types of vitreous enamel frits—which are widely used in the large scale production of cookers, ranges, baths, sinks, reflectors, holloware and kitchen equipment—Metal Porcelains, Ltd., as consultants to the industry, recommend and, if required, supply a wide range of vitreous enamelling plant and equipment manufactured by other members of the Incandescent group. In addition, M.P.L. chemists and technicians are available to assist and advise in overcoming enamelling difficulties. A new leaflet dealing with these activities bears the title " A Complete Vitreous Enamelling Service," and is available from the company at Cornwall Road, Smethwick 40, Staffs.

DEVELOPMENTS are continuously being made by industrial gas appliance manufacturers and by the regional gas boards themselves in the design of equipment for a wide range of industries. With the object of bringing to the attention of foundry personnel some of the developments in the application of gas to the foundry, the Gas Council has published a brochure—" Modern Foundry Practice "—which covers both ferrous and non-ferrous (including light metal) foundries. Applications mentioned range from the drying of moulding sand to the heat treatment of the finished product and include mould drying, melting, heating cupola blast, enamelling, etc.

A MEMBER of the United Steel Cos., Ltd., Distington Engineering Co., Ltd., started as an iron foundry and engineering works in 1946, and has since developed into one of the largest modern iron foundries in Europe, specialising in the production of ingot moulds, bottom plates and slag ladles. The plant consists of three manufacturing divisions—the iron foundry, the steel fabricating shop and the machine and assembly shop—all co-ordinated in a modern production-flow system. A 36-page illustrated booklet describes the foundry, which occupies some two-thirds of the plant, and was the first ingot mould foundry in Europe to achieve a production of more than 2,800 tons of finished castings per week.

THE new issue of the *Inco-Mond Magazine*, No. 18, includes articles on the ubiquitous applications of nickel-containing materials as well as an article on rhodium-plated silverware. A feature in this issue on s.s. *Canberra* shows the vital part nickel plays in the construction and easy running of the ship. The major uses are in the propellers, davits, condensers, boilers, stabilisers, cutlery and compasses. Further articles deal with the stainless-steel plant used in making Acrilan synthetic fibre ; the constructional nickel-steels in the gear-box and steering mechanisms of the " E " type Jaguar ; the use of nickel-alloy steels for the main-shaft of the Denny-Brown ships' stabilisers ; permanent magnets in the remote-reading ship's compass ; and Inconel X heat-resisting alloy as used in the skin of the X-15 rocket plane as well as various grades of nickel stainless-steel in the engine. The publication is obtainable free on request from The International Nickel Co. (Mond), Ltd., Thames House, Millbank, London, S.W.1.

IT is just four years since production of the first plastic-coated steel sheet in this country, Stelvetite, was launched with confidence. That confidence has since been justified by the increasing advantage being taken of the scope offered by this material, and the September issue of *John Summers' Review*—unlike previous issues devoted to a specific use—reflects the widespread use of the material in architecture and industry, in ship-building and post office, and in hospital and home.

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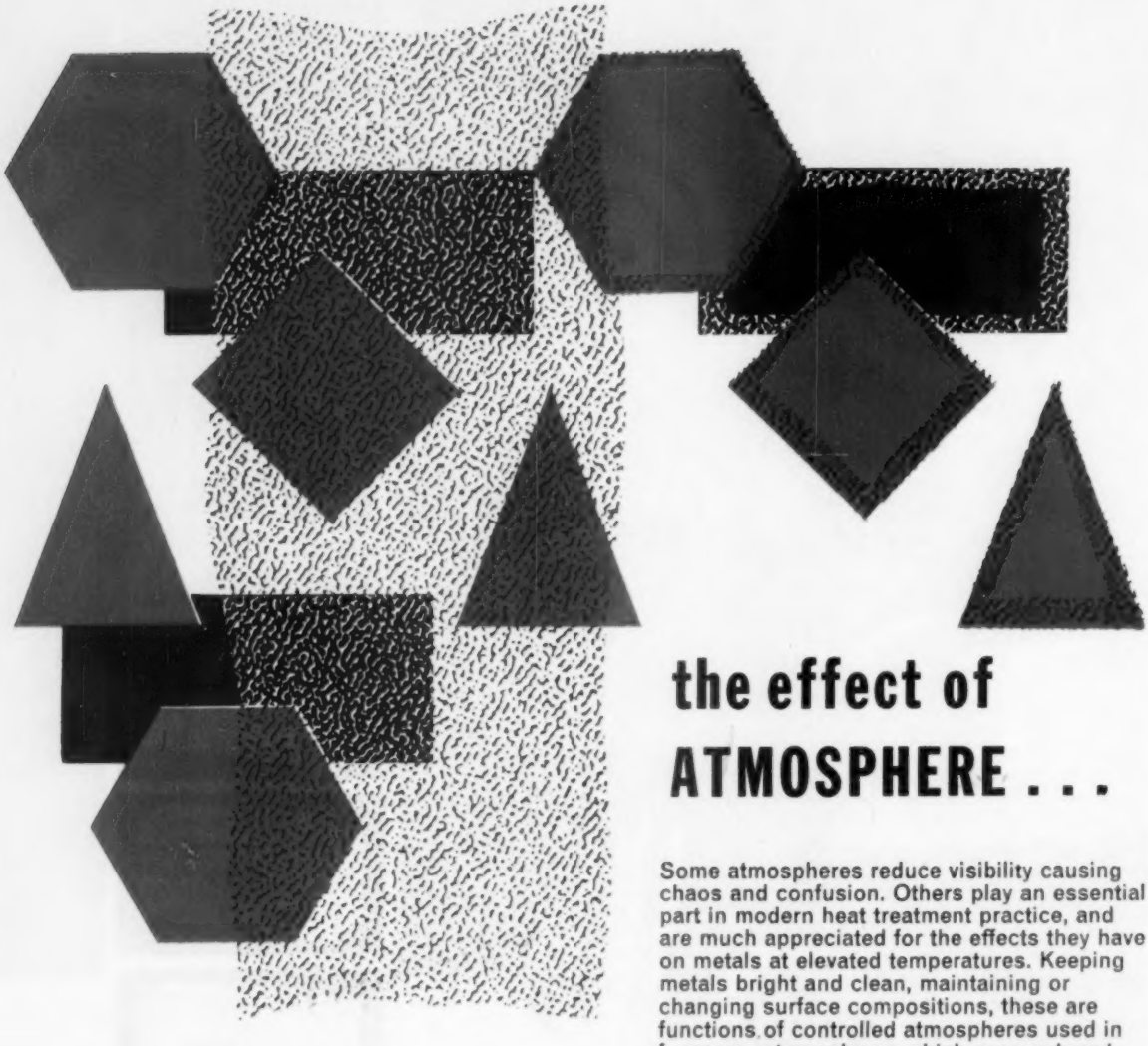

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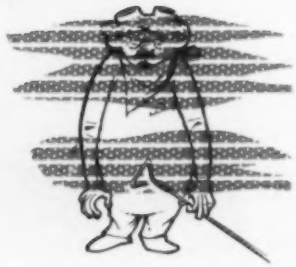

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INSTRUMENTS AND MATERIALS
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The Spectrographic Analysis of Alloys by a Solution Atomisation Technique

By R. A. Bingham

Midland Metallurgical Laboratories Limited

One of the difficulties in spectrographic analysis is the necessity for the use of standards very similar in composition to the unknown sample. The maintenance of the large stocks of standards required by a laboratory called upon to deal with a wide range of alloys would be both difficult and expensive. The author describes a means of overcoming this problem by a solution atomising technique, and presents results obtained on aluminium alloys, brasses, tin-bronzes and gunmetals.

IN the spectrographic analysis of alloys, particularly those of aluminium, an inherent difficulty is the necessity for the use of standards very similar in composition to the unknown sample in order to avoid inter-elemental effects. Another factor of some importance is the metallurgical history of the samples and standards.

In an independent laboratory, samples may be received in any one of a number of forms, ranging from drillings to large castings or forgings, and the difficulty and expense of obtaining a large range of comparable standards led to a study of means of reducing all the samples to the same state. Remelting was considered for certain alloys, but was rejected as being open to many difficulties and possible sources of error. Eventually, taking the samples into solution seemed to offer most hope of success and the method described below is the outcome of experiments on these lines.

The solution atomisation technique was developed primarily for aluminium alloys, and its use was subsequently extended to other alloys. Experience has confirmed that comparable standards are unnecessary, and no inter-elemental effects have so far been detected. Any sample received can be reduced to the same state by dissolving under standard conditions into a clear solution. Standards can therefore be prepared easily and accurately, thus saving considerable expense in the purchase of reliable standards. Experiments have shown that it is desirable to dissolve the sample in the least possible amount of solvent where maximum sensitivity in the spectra is required.

Details of Atomiser

The atomiser (Fig. 1) is constructed from glass tubing, and is held in a stand with a drip tray underneath it. A polythene tube from the lower limb of the atomiser dips into a beaker of the solution, and air or oxygen from a cylinder is blown as a jet across the upper end of the tube dipping into the solution. Solution is thus drawn up the tube and converted into a spray. As low a pressure as possible is advisable above the point where the mist forms, as excess spray tends to suppress and weaken the spectrum line densities: a steady pressure must be maintained throughout the exposure. The nozzles must be kept at a reasonable distance from the discharge to avoid it shorting on to them. They should be clamped tightly in position to avoid movement, which affects the spray considerably.

A cell (Fig. 2) was constructed from clear Perspex to contain the mist and prevent its drifting on to adjacent apparatus. The atomiser nozzle is inserted through a small hole in the side of the cell, and light from the

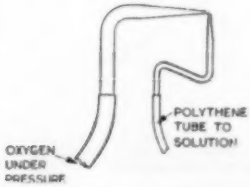


Fig. 1.—Sketch of the atomiser.

DIMENSIONS	
HEIGHT	87 mm.
WIDTH	55 mm.
DEPTH	26 mm.
UPPER HOLE DIAMETER	17 mm.
LOWER HOLE DIAMETER	12 mm.
WINDOW	18 x 18 mm.
SUCTION EXIT DIAMETER	12 mm.

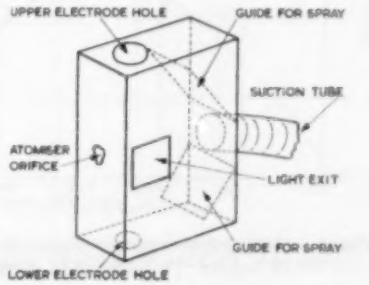


Fig. 2.—Sketch of the Perspex cell.

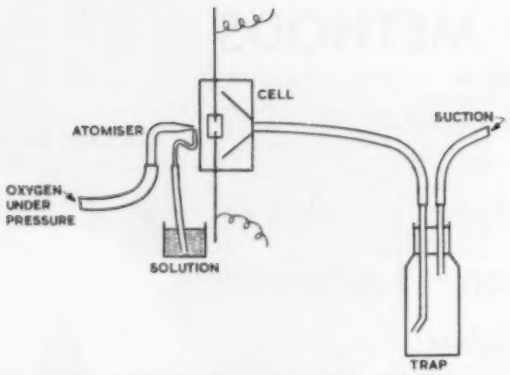


Fig. 3.—General arrangement of the apparatus.

discharge passes through a larger hole in the face of the cell to the slit of the spectrograph. The two holes for the electrodes are situated one at the top and the other at the bottom of the cell, the top hole being the larger of the two to prevent the spark from short-circuiting down the walls of the cell. Some solution runs down the lower electrode into a drip tray. The acid attacks the metal claws holding the rod, so a rubber apron is fitted just above the claw to deflect the acid into the drip tray. On the side of the cell opposite the atomiser orifice is a hole with a tube inserted which leads to a suction pump : this draws away the mist as it passes through the discharge. A trap is placed along this tube to catch the mist after extraction. It is preferable to be able to open up the cell for cleaning, as it becomes coated with powdered graphite from the electrodes where the inter-exposure distilled water spray, does not reach. The cell is held by a stand which is independent of the spark stand, so that both electrodes can be freely moved.

Other Apparatus Used

The method has been applied to aluminium alloys, brasses, tin-bronzes and gunmetals, the apparatus and settings used being the same in each, with the exception that for aluminium alloys the exposure was 80 seconds as compared with the 60 seconds for the copper alloys. Details of the apparatus are set out below :—

Spectrograph	Hilger Medium Quartz E498.
Slit length	1·00 mm.
Slit width	0·015 mm.
Condensing lens	F1026 focused on collimator.
Output	15 kV.
Capacity	0·005μF.
Inductance	0·03 mH.
Source-slit distance	38 cm.
Electrodes	JM4B graphite, flat-tipped.
Analytical gap	4 mm.
Exposures	
Aluminium alloys	80 sec.
Brasses	60 sec.
Tin-bronzes	60 sec.
Gunmetals	60 sec.
Atomising pressure	1 lb./sq. in. (depending on nozzle settings).
Plate	Kodak B10.
Development	3 min. in 1 : 2 Kodak D19b at 20° C.
Fixing	3 min. in Kodak Acid Hypo.

The plates were read on a Hilger non-recording microphotometer.

Operating Procedure

The compressed air cylinder is opened and set at the required pressure, which is maintained in the system throughout the series of exposures, the gauge being checked regularly to ensure that the pressure remains steady. The beaker of solution is placed under the atomiser and on dipping the polythene tube into it the spray starts. The spark is then switched on, the electrode gap adjusted, and the slit shutter opened for the exposure. At the end of the exposure the slit is closed, the spark switched off and the beaker of solution removed, to be replaced by a beaker of distilled water for the purpose of cleaning the entire apparatus. The beaker of solution is meanwhile topped-up and replaced under the atomiser to recommence the cycle.

The same pair of electrodes can be used throughout the series of exposures of both standards and samples, provided that the inter-exposure swilling is thorough. No carry-over of the previous solution has been detected when a spray of distilled water passing through the discharge has been exposed. The spark gap must be carefully adjusted to take care of the pitting of the electrode tips : the lower rod pits heavily on the side nearest to the atomiser.

When sparking aluminium solution it tends to run about on the electrodes and deposit as a solid on the upper rod : this must be removed before the next

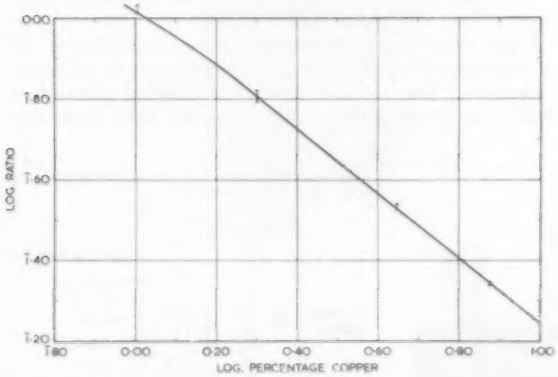


Fig. 4.—Calibration curve for copper in aluminium alloys: line pair, Cu 2246·9/Al 2269 ; range, 1·0–10·0%.

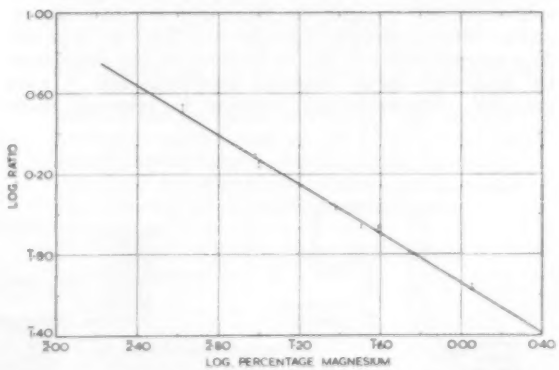


Fig. 5.—Calibration curve for magnesium in aluminium alloys : line pair, Mg 2852·4/Al 2816·1 ; range, 0·01–1·5%.

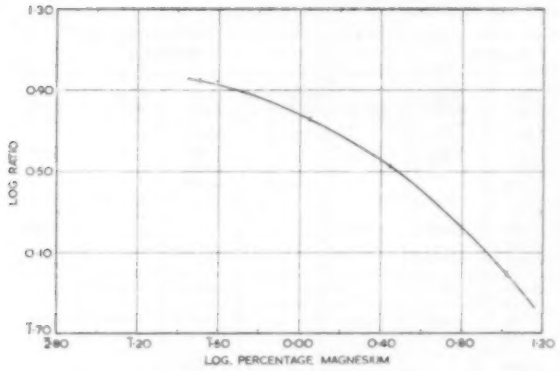


Fig. 6.—Calibration curve for magnesium in aluminium alloys : line pair, Mg 2779·8/Al 2816·1 ; range, 0·3–10·0%.

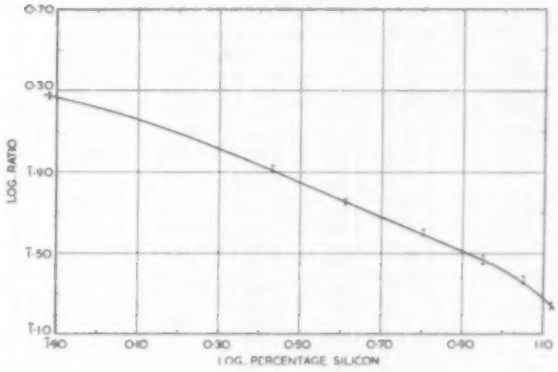


Fig. 7.—Calibration curve for silicon in aluminium alloys : line pair, Si 2516·2/Al 3057·1 ; range, 0·75–13·0%.

exposure. It is not advisable to use the same pair of electrodes for different samples of aluminium, as some carry-over is found to be present due to the very concentrated solutions used. In the case of other alloys very little deposition on the upper electrode occurs during sparking.

If the spray stops functioning during an exposure a dense spectrum results ; the spark should remain steady throughout the exposure. Standards are run through alternately with samples to take care of variations in the plate emulsion. The plate is then developed, washed in distilled water and dried.

The microphotometer slit width is set at 0·14 mm. (optical magnification × 10) and the length of the slit set at three-quarters of the length of the line read. The clear plate is set at 500 mm. on the galvanometer.

Method and Results for Various Alloy Groups

Aluminium Alloys

Preparation of Solution

Weigh 2 g. of sample into a 250 ml. beaker, add 50 ml. of 20% sodium hydroxide solution, cover, and digest slowly in low bulk. Cool, dilute a little, and add 45 ml. of 40% sulphuric acid. Heat (but do not boil) until the aluminium hydrate is in solution and add a few drops of hydrogen peroxide (10 vols.—50 ml.) from a dropping bottle until the solution clears. Cool in a water bath and bulk-up to 100 ml. with distilled water.

A 2 g. sample is sufficient for ten exposures if completely exhausted : half of all quantities quoted can be used in routine work.

Plate Reading

At the wavelengths of Ti 3349, Ni 3414·7 and Zn 3345 the background interferes, so correction is made by using the neighbouring background and setting the galvanometer reading at 500 mm. at this position. The line deflection is then taken and used directly for the estimation of the content as long as the amount is low. For higher amounts a line ratio is taken with Al 3057·1, which is also background corrected, and the normal procedure taken as with the other line pairs

Line Pairs

The line pairs used and the range covered in each case were as follows :—

Line Pairs		*Range Covered* (%)
Cu 2242·6	Al 2269·0	1·0 – 10·0
Cu 2246·9	Al 2269·0	
Cu 3247	Al 2816·1	0·01 – 1·0
Cu 3274	Al 2816·1	

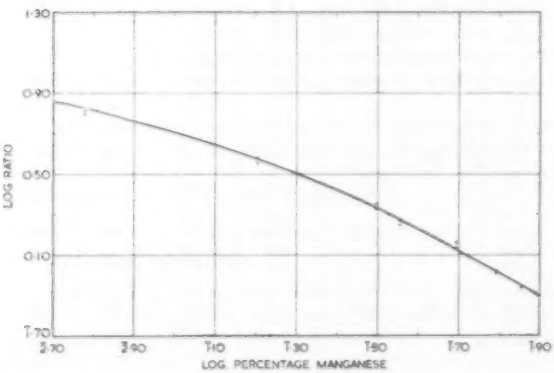


Fig. 8.—Calibration curve for manganese in aluminium alloys : line pair, Mn2593·7/Al 2816·1 ; range, 0·05–1·0%.

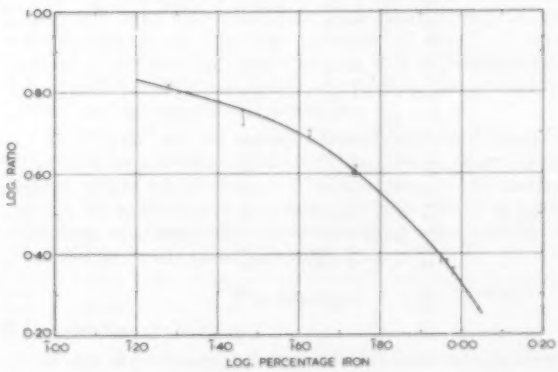


Fig. 9.—Calibration curve for iron in aluminium alloys : line pair, Fe 2599·4/Al 2816·1 ; range, 0·1–1·0%.

TABLE I.—RESULTS OF EXPOSURES OF EIGHT ALUMINIUM ALLOY STANDARDS

		Copper				Magnesium				Magnesium			
Standard Alloy	Spectrum No.	Cu 2246·9/ Al 2269	Log Ratio	Log Cu %	Cu %	Mg 2852·4/ Al 2816·1	Log Ratio	Log Mg %	Mg %	Mg 2779·8/ Al 2816·1	Log Ratio	Log Mg %	Mg %
LM 12	1	0·173	$\bar{1}$·238	1·0013	10·03	0·855	$\bar{1}$·932	$\bar{1}$·591	0·39	8·23	0·915	$\bar{1}$·591	0·39
	2	0·175	$\bar{1}$·243			0·862	$\bar{1}$·936			8·51	0·930		
	3	0·175	$\bar{1}$·243			0·836	$\bar{1}$·933			8·62	0·958		
	4	0·183	$\bar{1}$·263			0·824	$\bar{1}$·916			8·82	0·946		
LM 1	5	0·219	$\bar{1}$·340	0·875	7·50	1·92	0·283	$\bar{2}$·982	0·096	—	—		0·096
	6	0·222	$\bar{1}$·346			1·96	0·292			—	—		
	7	0·219	$\bar{1}$·340			1·96	0·292			—	—		
	8	0·222	$\bar{1}$·346			1·98	0·297			—	—		
LM 4	9	0·337	$\bar{1}$·528	0·647	4·44	3·18	0·502	$\bar{2}$·623	0·042	—	—		0·042
	10	0·338	$\bar{1}$·529			3·50	0·544			—	—		
	11	0·339	$\bar{1}$·530			3·42	0·534			—	—		
	12	0·347	$\bar{1}$·540			3·48	0·542			—	—		
LM 4	13	0·619	$\bar{1}$·792	0·301	2·00	0·874	$\bar{1}$·942	$\bar{1}$·504	0·319	8·88	0·948	$\bar{1}$·504	0·319
	14	0·629	$\bar{1}$·806			0·880	$\bar{1}$·935			8·98	0·953		
	15	0·644	$\bar{1}$·809			0·865	$\bar{1}$·937			8·61	0·935		
	16	0·662	$\bar{1}$·821			0·867	$\bar{1}$·938			8·78	0·944		
D.T.D.324	17	1·035	0·015	0·094	1·01	0·437	$\bar{1}$·641	0·053	1·13	5·81	0·764	0·053	1·13
	18	1·050	0·013			0·427	$\bar{1}$·630			5·67	0·754		
	19	1·080	0·033			0·450	$\bar{1}$·653			5·83	0·766		
	20	1·025	0·011			0·443	$\bar{1}$·646			5·73	0·758		
LM 6	21	—	—	—	0·05	1·075	0·031	$\bar{1}$·380	0·24	—	—	—	0·24
	22	—	—			1·050	0·021			—	—		
	23	—	—			1·065	0·027			—	—		
	24	—	—			1·095	0·039			—	—		
LM 6	25	—	—	—	0·13	1·77	0·248	$\bar{1}$·000	0·10	—	—		0·10
	26	—	—			1·71	0·233			—	—		
	27	—	—	—		1·81	0·258			—	—		
	28	—	—			1·76	0·246			—	—		
B.C.S.262	29	—	—	—	0·03	—	—	—	10·57	0·973	$\bar{1}$·988	1·023	10·57
	30	—	—	—		—	—			0·991	$\bar{1}$·996		
	31	—	—			—	—			1·010	0·004		
	32	—	—			—	—			0·974	$\bar{1}$·989		

		Silicon				Manganese				Iron			
Standard Alloy	Spectrum No.	Si 2516·2/ Al 3057·1	Log Ratio	Log Si %	Si %	Mn 2593·7/ Al 2816·1	Log Ratio	Log Mn %	Mn %	Fe 2599·4/ Al 2816·1	Log Ratio	Log Fe %	Fe %
LM12	1	1·86	0·270	$\bar{1}$·881	0·76	1·40	0·146	$\bar{1}$·695	0·495	3·92	0·593	$\bar{1}$·740	0·55
	2	1·82	0·260			1·45	0·161			4·17	0·620		
	3	1·94	0·288			1·45	0·161			4·11	0·614		
	4	1·95	0·290			1·37	0·137			4·05	0·608		
LM 1	5	0·860	$\bar{1}$·935	0·430	2·70	1·77	0·248	$\bar{1}$·556	0·36	2·40	0·380	$\bar{1}$·949	0·89
	6	0·800	$\bar{1}$·903			1·86	0·270			2·50	0·398		
	7	0·800	$\bar{1}$·903			1·81	0·258			2·42	0·384		
	8	0·793	$\bar{1}$·900			1·80	0·255			2·46	0·391		
LM 4	9	0·549	$\bar{1}$·740	0·611	4·08	2·12	0·326	$\bar{1}$·496	0·313	2·28	0·358	$\bar{1}$·980	0·955
	10	0·553	$\bar{1}$·743			2·17	0·337			2·31	0·364		
	11	0·578	$\bar{1}$·762			2·19	0·340			2·33	0·367		
	12	0·580	$\bar{1}$·763			2·24	0·350			2·24	0·350		
LM 4	13	0·416	$\bar{1}$·619	0·804	6·36	0·874	$\bar{1}$·942	$\bar{1}$·854	0·714	4·90	0·690	$\bar{1}$·626	0·423
	14	0·398	$\bar{1}$·600			0·884	$\bar{1}$·947			4·98	0·697		
	15	0·394	$\bar{1}$·596			0·889	$\bar{1}$·949			4·97	0·696		
	16	0·389	$\bar{1}$·590			0·889	$\bar{1}$·949			5·11	0·708		
D.T.D.324	17	0·243	$\bar{1}$·386	1·052	11·28	7·61	0·881	$\bar{2}$·699	0·05	3·93	0·594	$\bar{1}$·732	0·54
	18	0·225	$\bar{1}$·352			7·32	0·865			3·94	0·596		
	19	0·231	$\bar{1}$·364			7·85	0·895			3·95	0·597		
	20	0·229	$\bar{1}$·360			7·44	0·872			4·04	0·606		
LM 6	21	0·308	$\bar{1}$·489	0·950	8·91	1·050	0·021	$\bar{1}$·792	0·62	2·44	0·387	$\bar{1}$·964	0·92
	22	0·299	$\bar{1}$·477			1·035	0·015			2·42	0·384		
	23	0·282	$\bar{1}$·450			1·030	0·013			2·42	0·384		
	24	0·286	$\bar{1}$·456			1·035	0·015			2·41	0·382		
LM 6	25	0·1815	$\bar{1}$·259	1·130	13·19	3·60	0·556	$\bar{1}$·204	0·16	5·25	0·720	$\bar{1}$·462	0·29
	26	0·1730	$\bar{1}$·238			3·66	0·564			5·72	0·757		
	27	0·1714	$\bar{1}$·234			3·81	0·581			5·56	0·745		
	28	0·1690	$\bar{1}$·228			3·71	0·569			5·42	0·734		
B.C.S.262	29	—	—	—	0·10	6·32	0·801	$\bar{2}$·778	0·06	6·55	0·816	$\bar{1}$·279	0·19
	30	—	—			6·43	0·808			6·59	0·819		
	31	—	—			6·40	0·806			6·59	0·819		
	32	—	—			6·28	0·798			6·44	0·809		

TABLE II.—RESULTS OF A REPRODUCIBILITY TEST ON A B.S.1490—LM 2 ALLOY

Spectrum No.	Cu %	Mg %	Si %	Fe %	Mn %	Ni %	Zn %	Ti %
1	2·19	0·0250	10·79	0·841	0·288	0·180	1·32	0·056
2	2·23	0·0271	11·35	0·845	0·311	0·210	1·34	0·056
3	2·29	0·0257	11·30	0·841	0·318	0·220	1·43	0·056
4	2·23	0·0243	11·35	0·849	0·318	0·240	1·49	0·066
5	2·37	0·0246	11·27	0·798	0·294	0·215	1·36	0·063
6	2·26	0·0251	10·69	0·811	0·312	0·235	1·43	0·058
7	2·27	0·0237	11·43	0·849	0·311	0·245	1·46	0·062
8	2·34	0·0251	11·04	0·811	0·309	0·190	1·38	0·056
9	2·27	0·0246	11·04	0·828	0·324	0·220	1·39	0·063
10	2·25	0·0250	11·27	0·832	0·325	0·230	1·51	0·059
11	2·27	0·0246	11·09	0·841	0·324	0·235	1·48	0·063
Mean Content	2·27	0·0250	11·15	0·831	0·312	0·220	1·43	0·060
Estimated Standard Deviation (±)	±0·050	±0·0009	±0·24	±0·02	±0·013	±0·021	±0·08	±0·0037
Estimated Standard Deviation (%)	±2·2	±3·5	±2·2	±2·2	±4·1	±9·5	±5·6	±6·2

Line Pairs		*Range Covered (%)*
Mg 2852	Al 2816·1	0·01 – 1·5
Mg 2779·8	Al 2816·1	0·3 – 10·0
Si 2516·2	Al 3057·1	0·75 – 13·0
Si 2881	Al 2816·1	0·01 – 2·0
Fe 2599·4	Al 2816·1	0·1 – 1·0
Mn 2593·7	Al 2816·1	0·05 – 1·0
Ti 3349	Background 3348	0·01 – 0·25
Ni 3414·7	Background 3410	0·15 – 1·0
Zn 3345	Background 3344	0·5 – 5·0

Standardisation and Reproducibility Test

Eight standards were exposed four times each, the results being set out in Table I and plotted in Figs. 4–9. A ninth standard was exposed which contained 2·86% of magnesium, which was also plotted.

The results of a reproducibility test on a B.S. 1490—LM2 alloy, exposed eleven times, are given in Table II. The manganese and magnesium reproducibility is not as good as usual, and the nickel, zinc and titanium results are somewhat erratic due to the lines being faint against the background. Zinc is usually insensitive, it being impossible to detect it below 0·5%. For lower amounts a method involving the chemical separation of other elements from the solution followed by concentration of the latter is necessary. Trouble may be experienced with silicon results if glass beakers are used for preparation. Samples retained for any period should be stored in polythene bottles.

No alloy effects have been detected, and all alloys are computed from the same graphs. Unfortunately, standards have to be included on the same plate as samples, as graph shifts do occur between each series of exposures. Synthetic standards can be made and the amount of graph movement determined with them, thus saving the considerable expense of replacing the standards.

All elements can be estimated to high contents with accuracies equal to those quoted, particularly copper and magnesium, and no inter-elemental effects have been detected within the ranges used.

Copper-Zinc Alloys

Preparation of Sample

Weigh 2 g. of sample into a 250 ml. beaker, add 20 ml. of 40% nitric acid, heat and allow to dissolve completely. Make bulk up to 40 ml. with distilled water.

Under present conditions 10 ml. of solution is sufficient for one exposure.

Preparation of Standards

Prepare standards synthetically from pure copper strip and pure zinc weighed out in the following proportions :—

Identity	*Estimated Zinc (%)*	*Weight of Zinc (g.)*	*Weight of Copper (g.)*
Std. 1·0	1·0	0·04	3·96
Std. 3·0	3·0	0·12	3·88
Std. 6·0	6·0	0·24	3·76
Std. 10·0	10·0	0·40	3·60
Std. 20·0	20·0	0·80	3·20
Std. 30·0	30·0	1·20	2·80
Std. 40·0	40·0	1·60	2·40

Dissolve the metals in 40 ml. of 40% nitric acid and bulk-up to 80 ml. with distilled water.

Line Pairs

The line pairs used and the range covered in each case were as follows :—

Line Pairs		*Range Covered (%)*
Zn 3302·6	Cu 3290·5	1·0 – 10·0
Zn 3282·3	Cu 3307·9	3·0 – 50·0

Standardisation and Reproducibility Test

A series of standards was prepared under normal conditions and a 60 : 40 brass sample was used for the reproducibility test, 6·6 g. of the sample being dissolved and made up to 132 ml. of solution. Each standard was exposed four times. The same pair of electrodes was used for the standards, and a fresh pair for the reproducibility test. The results set out in Table III include the standardisations and the reproducibility test. The standardisations are plotted in Figs. 10 and 11.

There should be no effects from other elements present, provided that they total not more than 0·5%, in the determination of the high contents of zinc. If other elements are present to any extent, it is advisable to use an added internal standard, so avoiding the weakening effect on the copper line densities.

Standards can be stored conveniently and must be included on the plate along with samples to cater for the graph shifts which occur. The accuracy of the method could be appreciably increased by the use of a direct reading spectrograph, thus avoiding the effects of variations in the plate emulsion.

Tin-Bronzes

Preparation of Solution

Weigh 2 g. of sample into a 250 ml. beaker, add 20 ml. of aqua regia, cover and allow the sample to dissolve completely. Make bulk up to 40 ml. with distilled water.

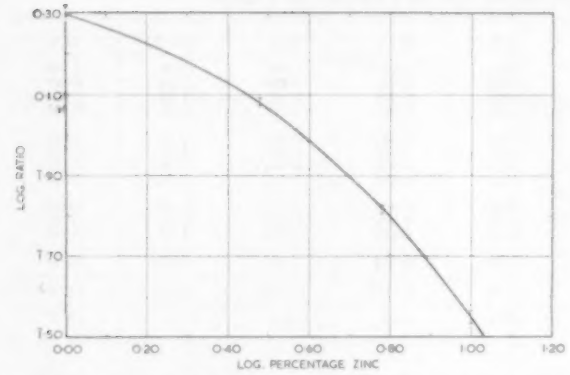


Fig. 10.—Calibration curve for zinc in copper-zinc alloys : line pair, Zn 3302·6/Cu 3290·5 ; range 1·0–10·0%.

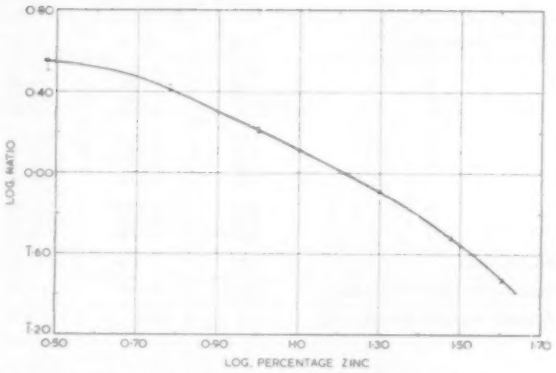


Fig. 11.—Calibration curve for zinc in copper-zinc alloys : line pair, Zn 3282·3/Cu 3307·9 ; range, 3·0–50·0%.

Under present conditions 10 ml. of solution is sufficient for one exposure.

Preparation of Standards

Prepare standards synthetically from pure copper strip and pure tin weighed out in the following proportions :—

Identity	*Estimated Tin (%)*	*Weight of Tin (g.)*	*Weight of Copper (g.)*
Std. 1·0	1·0	0·04	3·96
Std. 2·0	2·0	0·08	3·92
Std. 3·0	3·0	0·12	3·88
Std. 6·0	6·0	0·24	3·76
Std. 10·0	10·0	0·40	3·60

TABLE III.—RESULTS OF EXPOSURES OF SEVEN COPPER-ZINC STANDARDS AND A REPRODUCIBILITY TEST ON 60 : 40 BRASS

*Sample	Spectrum No.	Zn 3302·6 Reading	Cu 3290·5 Reading	Zn 3302·6 / Cu 3290·5	Log Ratio	Zn 3282·3 Reading	Cu 3307·9 Reading	Zn 3282·3 / Cu 3307·9	Log Ratio	Log Zn %	Zn %
Std. 1·0 ..	1	362	185	1·96	0·292	275	71	3·87	0·588	0·000	1·00
	2	352	168	2·10	0·322	257	65	3·95	0·597		
	3	362	168	1·95	0·290	273	73	3·74	0·573		
	4	350	171	2·05	0·312	258	66	3·91	0·592		
Std. 3·0 ..	5	216	180	1·20	0·079	246	68	3·62	0·559	0·477	3·00
	6	218	178	1·22	0·086	245	69	3·55	0·550		
	7	218	176	1·24	0·093	244	69	3·54	0·549		
	8	233	199	1·175	0·074	261	82	3·18	0·502		
Std. 6·0 ..	9	126	189	0·666	$\bar{1}$·824	212	78	2·72	0·435	0·778	6·00
	10	133	200	0·665	$\bar{1}$·823	217	85	2·55	0·407		
	11	127	195	0·651	$\bar{1}$·814	209	81	2·58	0·412		
	12	127	198	0·641	$\bar{1}$·807	212	82	2·59	0·413		
Std. 10·0 ..	13	81	236	0·343	$\bar{1}$·535	180	112	1·610	0·207	1·00	10·00
	14	81	234	0·346	$\bar{1}$·539	180	110	1·635	0·214		
	15	91	247	0·368	$\bar{1}$·566	192	119	1·615	0·208		
	16	83·5	236	0·354	$\bar{1}$·549	184	110	1·675	0·223		
Std. 20·0 ..	17	30	245	0·123	$\bar{1}$·090	97	121	0·802	$\bar{1}$·904	1·301	20·00
	18	30	241	0·125	$\bar{1}$·097	98	121	0·810	$\bar{1}$·909		
	19	30	238	0·126	$\bar{1}$·100	98	118	0·814	$\bar{1}$·911		
	20	30	240	0·125	$\bar{1}$·097	97	120	0·809	$\bar{1}$·908		
Std. 30·0 ..	21	—	—	—	—	60	124	0·484	$\bar{1}$·685	1·477	30·00
	22					55	113	0·486	$\bar{1}$·687		
	23					59	124	0·476	$\bar{1}$·678		
	24					59	126	0·468	$\bar{1}$·670		
Std. 40·0 ..	25	—	—	—	—	52	174	0·299	$\bar{1}$·476	1·602	40·00
	26					52	175	0·297	$\bar{1}$·473		
	27					53·5	178	0·301	$\bar{1}$·479		
	28					49	167	0·294	$\bar{1}$·468		
Brass (60:40)	29	—	—	—	—	36	129	0·279	$\bar{1}$·446	1·618	41·5
	30					40·5	146	0·277	$\bar{1}$·443	1·619	41·6
	31*					50	173	0·289	$\bar{1}$·461	1·608	40·6
	32					44	152	0·289	$\bar{1}$·461	1·608	40·6
	33					40	143	0·280	$\bar{1}$·447	1·618	41·5
	34					41	144	0·285	$\bar{1}$·455	1·612	40·9
	35					40	141	0·284	$\bar{1}$·452	1·613	41·0
	36					39·5	136	0·290	$\bar{1}$·462	1·609	40·6
	37					40	140	0·286	$\bar{1}$·456	1·611	40·8
	38					37·5	134	0·280	$\bar{1}$·447	1·618	41·5
	39					35	126	0·278	$\bar{1}$·444	1·619	41·6

Average of eleven exposures on the brass gave Zn = 41·1%

Standard Deviation σ = ± 0·43%

= ± 1·00%

* Spectrum No. 31 was an exposure of 46 seconds as the spark began shorting onto the cell.

Dissolve the metals in 40 ml. of aqua regia and bulk-up to 80 ml. with distilled water.

Line Pairs

The line pairs used and the range covered in each case were as follows :—

Line Pairs		*Range Covered* (%)
Sn 3034·1	Cu 3036·1	1·0 – 10·0
Sn 3034·1	Cu 2961	1·0 – 10·0

These pairs give the best coverage over low and high contents, with extra accuracy over the middle region of the graph (Fig. 12). A line is drawn midway between the straight portions of the curves giving average values for the two curves.

Standardisation and Reproducibility Test

A series of standards was prepared under normal conditions, and a chemical standard and a phosphor-bronze containing some 7% tin were also dissolved for checking and the reproducibility test. Each standard was exposed four times. The same pair of electrodes was used throughout the test, the gap being adjusted between exposures without refacing the tips. The results set out in Table IV include the standardisations and the reproducibility test. The standardisations are plotted in Fig. 12.

Chemical analysis gave a figure of 9·96% tin for bronze "A" and 7·13% tin for bronze "B." The former also contained 4·5% of other elements, mainly lead and zinc. The presence of impurities does not greatly affect the result when they total less than 2%. The error to be expected from the presence of other elements can be calculated, as the copper lines weaken in proportion, and the conversion can be made with sufficient accuracy.

The percentage standard deviation obtained in the test is not as good as can be achieved when a new pair of electrodes is used, when the figure is about 1·0–1·5, but it shows good reproducibility under routine condition.

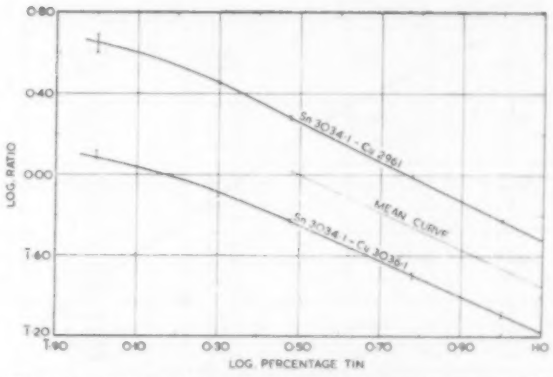


Fig. 12.—Calibration curves for tin in tin-bronzes : line pairs, Sn 3034·1/Cu 2961 and Sn 3034·1/Cu 3036·1 ; range, 1·0–10·0%.

Standards can be stored conveniently and must be included on the plate along with the samples to cater for the graph shifts which occur.

The maximum percentage measurable with this method has not been determined, but estimations of much higher contents should be possible with equal or improved accuracy. The method has been developed for the determination of zinc contents in brasses up to 50% with excellent accuracy. Under the conditions specified there is, however, a lower limit of 1% : to go below this figure would entail concentrating the solution and increasing the exposure time.

TABLE IV.—RESULTS OF EXPOSURE OF FIVE TIN BRONZE STANDARDS AND A BRONZE AND A REPRODUCIBILITY TEST ON A FURTHER BRONZE

Sample	Spectrum No.	Sn 3034·1 Reading	Cu 3036·1 Reading	Sn 3034 / Cu 3036	Log. Ratio	Cu 2961 Reading	Sn 3034 / Cu 2961	Log. Ratio	Log. Sn %	Sn %
Std. 1·0	1	278	210	1·325	0·122	57	4·98	0·697	0·000	1·00
	2	300	240	1·250	0·097	68	4·41	0·644		
	3	306	251	1·220	0·086	74	4·13	0·616		
	4	323	260	1·240	0·093	81	3·99	0·601		
Std. 2·0	5	188	235	0·800	$\bar{1}$·903	65	2·89	0·461	0·301	2·00
	6	182	225	0·809	$\bar{1}$·908	65	2·80	0·447		
	7	185	234	0·790	$\bar{1}$·898	65	2·85	0·455		
	8	189	233	0·810	$\bar{1}$·909	65	2·91	0·464		
Std. 3·0	9	152	259	0·586	$\bar{1}$·768	79	1·92	0·283	0·477	3·00
	10	160	272	0·588	$\bar{1}$·769	84	1·91	0·280		
	11	167	278	0·600	$\bar{1}$·778	88·5	1·89	0·277		
	12	163	270	0·603	$\bar{1}$·780	85	1·92	0·283		
Std. 6·0	13	94	291	0·323	$\bar{1}$·509	96	0·980	$\bar{1}$·991	0·778	6·00
	14	95	291	0·326	$\bar{1}$·513	97	0·980	$\bar{1}$·991		
	15	89	281	0·317	$\bar{1}$·501	90	0·989	$\bar{1}$·995		
	16	86	278	0·310	$\bar{1}$·491	86	1·000	0·000		
Std. 10·0	17	57·5	289	0·199	$\bar{1}$·299	97	0·593	$\bar{1}$·773	1·000	10·00
	18	66	312	0·212	$\bar{1}$·326	110	0·600	$\bar{1}$·778		
	19	63·5	307	0·207	$\bar{1}$·316	106	0·599	$\bar{1}$·777		
	20	60	298	0·202	$\bar{1}$·305	101	0·594	$\bar{1}$·774		
Bronze "A"	21	63·5	308	0·206	$\bar{1}$·314	110	0·578	$\bar{1}$·762	1·002	10·05
	22	57·5	285	0·202	$\bar{1}$·305	98	0·587	$\bar{1}$·770	1·005	10·12
Bronze "B"	23	74·5	280	0·266	$\bar{1}$·425	90	0·828	$\bar{1}$·918	0·860	7·24
	24	80	285	0·281	$\bar{1}$·449	97	0·825	$\bar{1}$·917	0·846	7·02
	25	84·5	293	0·288	$\bar{1}$·459	99	0·854	$\bar{1}$·932	0·854	6·82
	26	86	308	0·279	$\bar{1}$·446	106	0·811	$\bar{1}$·909	0·852	7·11
	27	79·5	292	0·272	$\bar{1}$·435	96	0·811	$\bar{1}$·909	0·848	7·05
	28	79	285	0·274	$\bar{1}$·438	93	0·848	$\bar{1}$·928	0·847	7·03
	29	81	300	0·270	$\bar{1}$·431	96	0·844	$\bar{1}$·926	0·851	7·10
	30	76	285	0·267	$\bar{1}$·427	92·5	0·822	$\bar{1}$·915	0·850	7·23

Average of the eight exposures on Bronze "B" gave Sn = 7·08%

Standard Deviation $\sigma = \pm 0{\cdot}13\%$ $= \pm 1{\cdot}8\%$

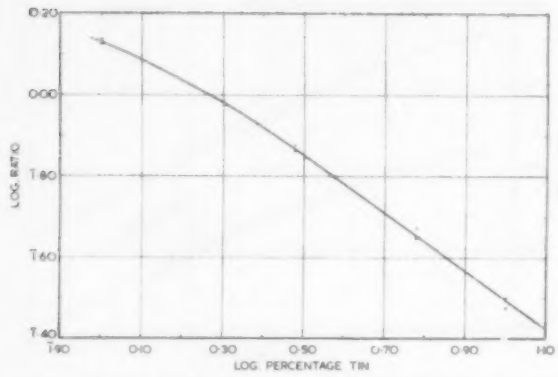


Fig. 13.—Calibration curve for tin in gunmetals: line pair, Sn 3034/Cr 3030·2; range, 1·0–10·0%.

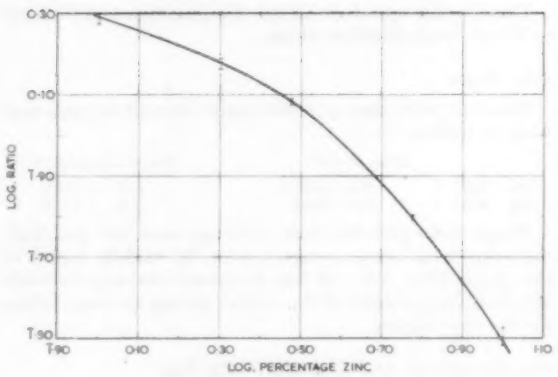


Fig. 14.—Calibration curve for zinc in gunmetals: line pair, Zn 3302/Cr 3324; range, 1·0–10·0%.

Gunmetals

Preparation of Solution

Weigh 2 g. of sample into a 250 ml. beaker and dissolve in 20 ml. aqua regia. Add 16 ml. of a solution of chromium trioxide made by dissolving 20 g. of crystals in 800 ml. of distilled water: the chromium is to serve as an internal standard. Bulk-up to 40 ml. with distilled water. If lead is present in amounts greater than 2% it crystallises as lead chloride: this must be removed by filtration.

Under present conditions 10 ml. of solution is sufficient for one exposure.

Preparation of Standards

Prepare standards synthetically from pure copper, strip, pure tin, pure zinc and pure nickel, weighed out in the following proportion:—

Identity	*Estimated (%)*				*Weight of (g.)*			
	Tin	*Zinc*	*Nickel*	*Copper*	*Tin*	*Zinc*	*Nickel*	*Copper*
Std. 1	1·0	10·0	0·5	95	0·05	0·50	0·025	4·75
Std. 2	2·0	6·0	0·8	80	0·10	0·30	0·04	4·00
Std. 3	3·0	3·0	1·0	75	0·15	0·15	0·05	3·75
Std. 4	6·0	2·0	2·0	90	0·30	0·10	0·10	4·50
Std. 5	10·0	1·0	3·0	85	0·50	0·05	0·15	4·25

The standards are not prepared so that the percentages total 100 in each case, as the use of a chromium internal

TABLE V.—RESULTS OF EXPOSURE OF FIVE GUNMETAL STANDARDS AND A BRONZE AND A REPRODUCIBILITY TEST ON A GUNMETAL

Sample	Spectrum No.	Zn 3302 Reading	Cr 3324 Reading	$\frac{\text{Zn 3302}}{\text{Cr 3324}}$	Log. Ratio	Log. Zn%	Zn %
Std. 1	1	46	137	0·336	$\bar{1}$·526	1·000	10·00
	2	38	123	0·309	$\bar{1}$·490		
	3	44·5	147	0·303	$\bar{1}$·481		
	4	46	148	0·311	$\bar{1}$·493		
Std. 2	5	93·5	148	0·632	$\bar{1}$·801	0·778	6·00
	6	79	128	0·618	$\bar{1}$·791		
	7	97	154	0·630	$\bar{1}$·799		
	8	100	161	0·621	$\bar{1}$·793		
Std. 3	9	190	159	1·195	0·077	0·477	3·00
	10	202	164	1·23	0·090		
	11	199	165	1·205	0·081		
	12	202	166	1·22	0·086		
Std. 4	13	268	173	1·55	0·190	0·301	2·00
	14	283	185	1·53	0·185		
	15	292	196	1·49	0·173		
	16	290	199	1·46	0·164		
Std. 5	17	365	193	1·89	0·277	0·000	1·00
	18	352	177	1·99	0·299		
	19	358	185	1·94	0·288		
	20	351	176	1·99	0·299		
Bronze "A"	21	260	155	1·68	0·225	0·1995	1·58
	22	268	163	1·645	0·216	0·220	1·66
Gunmetal "B"	23	134	196	0·684	$\bar{1}$·835	0·749	5·61
	24	117	183	0·640	$\bar{1}$·806	0·774	5·94
	25	124	190	0·652	$\bar{1}$·814	0·766	5·83
	26	121	184	0·658	$\bar{1}$·818	0·762	5·78
	27	117	179	0·653	$\bar{1}$·815	0·766	5·83
	28	119	186	0·640	$\bar{1}$·806	0·776	5·97
	29	120	183	0·655	$\bar{1}$·816	0·765	5·82
	30	115	172	0·657	$\bar{1}$·818	0·762	5·78
	31	119	185	0·643	$\bar{1}$·808	0·772	5·92

Average of nine exposures on Gunmetal "B" gave Zn = 5·83%
$\sigma = \pm 0·105\%$
Standard Deviation $= \pm 1·85\%$
Chemical Analysis of Bronze "A" Zn = 1·86%
Chemical Analysis of Gunmetal "B" Zn = 5·65%

TABLE VI.—RESULTS OF EXPOSURE OF FIVE GUNMETAL STANDARDS AND A BRONZE AND A REPRODUCIBILITY TEST ON A GUNMETAL

Sample	Spectrum No.	Sn 3034 Reading	Cr 3030 Reading	$\frac{\text{Sn 3034}}{\text{Cr 3030}}$	Log. Ratio	Log. Sn %	Sn %
Std. 1	1	186	138	1·35	0·130	0·000	1·00
	2	167	123	1·37	0·137		
	3	191	141	1·355	0·132		
	4	193	144	1·34	0·127		
Std. 2	5	142	146	0·972	$\bar{1}$·988	0·301	2·00
	6	122	128	0·953	$\bar{1}$·979		
	7	146	155	0·942	$\bar{1}$·974		
	8	149	155	0·961	$\bar{1}$·983		
Std. 3	9	115	155	0·742	$\bar{1}$·870	0·477	3·00
	10	118	161	0·733	$\bar{1}$·865		
	11	114	157	0·726	$\bar{1}$·861		
	12	110	158	0·753	$\bar{1}$·877		
Std. 4	13	75	167	0·450	$\bar{1}$·653	0·778	6·00
	14	78	166	0·470	$\bar{1}$·672		
	15	80	180	0·445	$\bar{1}$·648		
	16	79	172	0·460	$\bar{1}$·663		
Std. 5	17	54	172	0·314	$\bar{1}$·497	1·000	10·00
	18	49	155	0·316	$\bar{1}$·500		
	19	50	159	0·315	$\bar{1}$·498		
	20	45	150	0·300	$\bar{1}$·477		
Bronze " A "	21	42	131	0·320	$\bar{1}$·505	0·992	9·82
	22	43	135	0·319	$\bar{1}$·504	0·993	9·84
Gunmetal " B "	23	125	165	0·758	$\bar{1}$·880	0·455	2·85
	24	113	150	0·767	$\bar{1}$·885	0·448	2·81
	25	121	158	0·766	$\bar{1}$·884	0·450	2·82
	26	123	158	0·778	$\bar{1}$·891	0·459	2·75
	27	118	148	0·797	$\bar{1}$·902	0·423	2·64
	28	120	155	0·775	$\bar{1}$·889	0·442	2·77
	29	118	151	0·781	$\bar{1}$·893	0·436	2·73
	30	115	147	0·781	$\bar{1}$·893	0·436	2·73
	31	119	154	0·773	$\bar{1}$·888	0·444	2·78

Average of nine exposures on Gunmetal " B " gave Sn = 2·76%
$\sigma = \pm 0{\cdot}062\%$
Standard Deviation = ± 2·2%
Chemical analysis of Bronze " A " Sn = 9·96%
Chemical analysis of Gunmetal " B " Sn = 2·69%

standard eliminates the necessity for similar copper line densities. The different copper contents in the standards provide for an approximate determination of the copper contents of the samples, where required. The ranges covered are those normally expected in routine analysis, but they can easily be extended to higher ranges if required.

Dissolve the metals in aqua regia (10 ml./g.) and add the chromium trioxide solution (8 ml./g.). Bulk-up to 20 ml./g. with distilled water.

Line Pairs

The line pairs used and the range covered in each case were as follows :—

	Line Pairs			*Range Covered* (%)
Sn	3034·1	Cr	3030·2	1·0 – 10·0
Zn	3302	Cr	3324	1·0 – 10·0
Ni	3414	Cr	3421·2	0·5 – 3·0

Standardisation and Reproducibility Test

A series of standards was prepared under normal

TABLE VII.—RESULTS OF EXPOSURES OF FIVE GUNMETAL STANDARDS

Sample	Spectrum No.	Ni 3414 Reading	Cr 3420 Reading	$\frac{\text{Ni 3414}}{\text{Cr 3420}}$	Log. Ratio	Log. Ni %	Ni %
Std. 1	1	210	57	3·68	0·566	$\bar{1}$·699	0·50
	2	187	47·5	3·94	0·596		
	3	219	61	3·59	0·555		
	4	215	59·5	3·61	0·558		
Std. 2	5	159	62	2·56	0·408	$\bar{1}$·903	0·80
	6	132	51	2·59	0·413		
	7	166	67	2·48	0·395		
	8	177	71	2·49	0·396		
Std. 3	9	148	68	2·18	0·339	0·000	1·00
	10	150	72	2·08	0·318		
	11	151	70	2·16	0·335		
	12	155	73	2·12	0·326		
Std. 4	13	90	82	1·10	0·041	0·301	2·00
	14	93	86	1·08	0·033		
	15	103	95	1·085	0·035		
	16	102	94	1·085	0·035		
Std. 5	17	63·5	91	0·698	$\bar{1}$·844	0·477	3·00
	18	54	74	0·730	$\bar{1}$·863		
	19	57	84	0·679	$\bar{1}$·832		
	20	51	71	0·718	$\bar{1}$·856		

Nickel was not present in either test sample.
Percentage standard deviation normally obtained in routine is of the order of 2·0–3·0

conditions. A chemical standard bronze "A" was prepared as a check and a gunmetal sample "B" for the reproducibility test. Each standard was exposed four times, the chemical standard twice, and the gunmetal nine times. The same pair of electrodes was used throughout the test with the gap adjusted between exposures, without refacing the tips. The results set out in Tables V–VII include the standardisations and the reproducibility test. The standardisations are plotted in Figs. 13–15.

Standards can be stored conveniently and must be included on the plate with the samples to cater for the graph shifts which occur. With this method copper-zinc alloys and tin bronzes can be analysed using the same gunmetal standards, provided that chromium is added in the same proportions as for the gunmetals.

Conclusions

The accuracy of this type of analysis could probably be increased by the use of metallic electrodes which would not be attacked by the solutions and would not pit by the action of the spark. This would give a constant spark, but of course the material would have to be neutral to the analysis concerned.

The use of direct reading instruments would speed results and would probably increase accuracy by avoiding the effects of variations in the plate emulsion.

Recent work has tended to show that solutions of completely different composition from that of the sample, both containing the same added internal standard, can be used for direct comparison. For example, aluminium standards containing chromium as the internal standard and different contents of zinc can be used as standard to compare with brass samples with the same ratio of weight of chromium added to weight of sample.

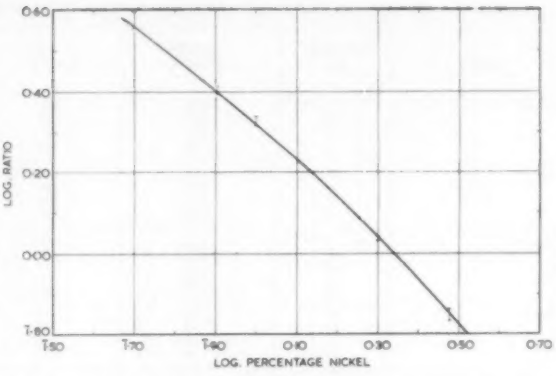


Fig. 15.—Calibration curve for nickel in gunmetals: line pair, Ni 3414/Cr 3421·2; range, 0·5–3·0%.

Acknowledgments

The author wishes to express his thanks to the directors and management of Midland Metallurgical Laboratories, Ltd., for permission to publish this work.

Resin-bonded Fabric Bearings for Atomic Power Stations

NUCLEAR engineering developments have introduced new problems in bearing design, requiring materials which can withstand heavy radiation, operate without oil or grease lubrication, and remain unaffected by immersion in "pond" water. United Coke and Chemicals Co., Ltd., have developed a new addition to their range of Orkot resin-bonded fabrics for this application. Known as Orkot Grade TL, it has undergone extensive radiation exposure and aqueous immersion tests and has been specified for the bearings for the fuel element handling equipment at both Hinkley Point and Sizewell atomic power stations. The new material is tough, hard wearing and has a low coefficient of friction with aqueous lubricants. For dry running conditions, it is available impregnated with graphite or MoS_2. Grade TL is dimensionally stable in the presence of water and has a remarkably high resistance to radiation damage.

N.E.L. Report for 1960

RESULTS of research on machine tools, ball bearings, fatigue at high temperatures, and extrusion of metals are some of the items of direct industrial interest included in the latest Annual Report of the National Engineering Laboratory,* which has recently been published. Instruments for measuring the air content of liquids and for determining the rate of flow of water in large pipes are other examples of new developments at the Laboratory which will find diverse application in industry.

Background research forms an important part of the Laboratory's work. The report gives details of the first stages of the synthesis of very hard materials (small diamonds were produced recently at N.E.L.); the preparation of new steam tables; the lubrication of gears; and the fracture of metals under combined creep and fatigue.

An account is also given of new research facilities including a master gear-generating machine, equipment for calibrating gas and oil flow meters, and rigs for testing the performance of fans. Sponsored work for individual firms has ranged from noise measurement in a factory to efficiency tests on a water turbine. The report also contains brief notes on all research in progress during the past year.

* National Engineering Laboratory Annual Report for 1960, published for D.S.I.R. by H.M. Stationery Office, price 3s. (by post 3s. 5d.).

TI in County Durham

TUBE INVESTMENTS, LTD., have acquired a 280 acre site at Washington, Co. Durham, for the long term development of its manufacturing capacity. The decision to purchase has been taken after full consultation with the Board of Trade, the local authorities and the district officials of the trades unions concerned. It is expected that preliminary site work will begin early in 1962 and that by 1965 some 750 men and women will be employed in the manufacture of steel tubing. The first factory will house a highly mechanised electric resistance welded tube mill incorporating many advanced engineering features, and subsequent factories will be erected in accordance with a development programme for the production of steel tubes and other products.

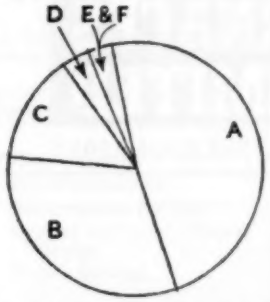
Factory Heating-1

The space heating of factories by electrical means can be achieved in a variety of ways which will be dealt with in the next Data Sheet.

Before deciding on any form of factory space heating—whether by means of electricity or not—it is as well to have clearly in mind all the components of the total annual running cost, and not merely the fuel cost, of the installation.

They are:

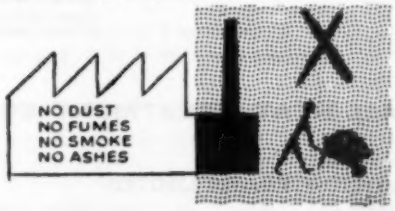
- **(A)** The cost of the fuel or the electricity,
- **(B)** Interest and depreciation on the capital cost of the installation,
- **(C)** Labour,
- **(D)** The cost of running auxiliary plant such as fans and pumps,
- **(E)** Maintenance,
- **(F)** Insurance.



In comparing fuel costs it should be borne in mind that electric heat is refined heat and has had all the fuss, bother and dirt of the conversion of fuel into heat taken out at the generating station.

In arriving at the true figures for capital cost and depreciation, maintenance, and insurance, those connected with such items as boilerhouse, chimney, fuel store and access road should be included; labour costs should include such tasks as ash disposal. None of these items occurs when electricity is used, although space will be required for the electric boiler and storage vessels in the case of the type (h) following.

Electricity provides the ideal answer to the requirements of the Clean Air Act, the impact of which has introduced an important new factor during the last few years.



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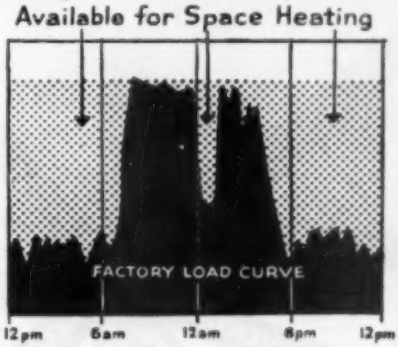
The following list gives the main types into which electric heating installations fall:

- (a) High temperature ("infra-red") overhead heaters operating at near red heat.
- (b) Medium temperature panels operating at surface temperatures of 400° to 600°F.
- (c) Extended surfaced heating in the shape of floorwarming operating at temperatures up to 80°F.
- (d) Oil and water filled radiators.
- (e) Tubular heaters.
- (f) Unit heaters.
- (g) Storage block heaters.
- (h) Electric boilers and water heaters operating in conjunction with hot water radiators or panels either with or without water storage.

All these methods of electric heating can be divided into two distinct classes:

- (a) Those that utilise electricity during "off-peak" hours and store the heat so generated for use at a later period.
- (b) Those that use electricity whenever the heating system is in use (i.e. direct electric heaters).

The use of a heat storage system in a small works on a block tariff takes advantage of the lower tariff offered for an off-peak supply, and in the larger factory on a Maximum Demand tariff means that the heating load will not incur any M.D. charge.



Alternatively there may be cases where the use of direct electric heaters can be integrated with other factory loads in such a way that they are not used during the factory peak periods and will thus incur no additional M.D. charge.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2.

Excellent reference books on the industrial and commercial uses of electricity and reprints of articles and papers are available. An example is "Higher Industrial Production with Electricity" (price 8/6 each or 9/- post free).

E.D.A. also have available on free loan in the U.K. a series of films on the industrial uses of electricity. Film and Book catalogues and Publications List sent on request.

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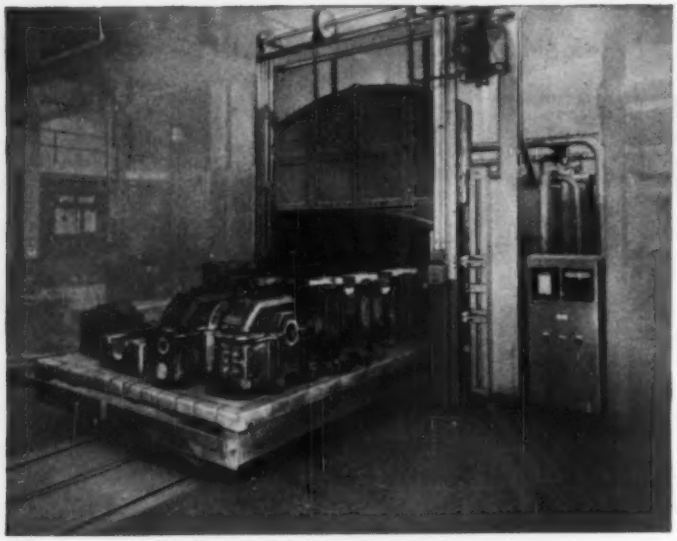

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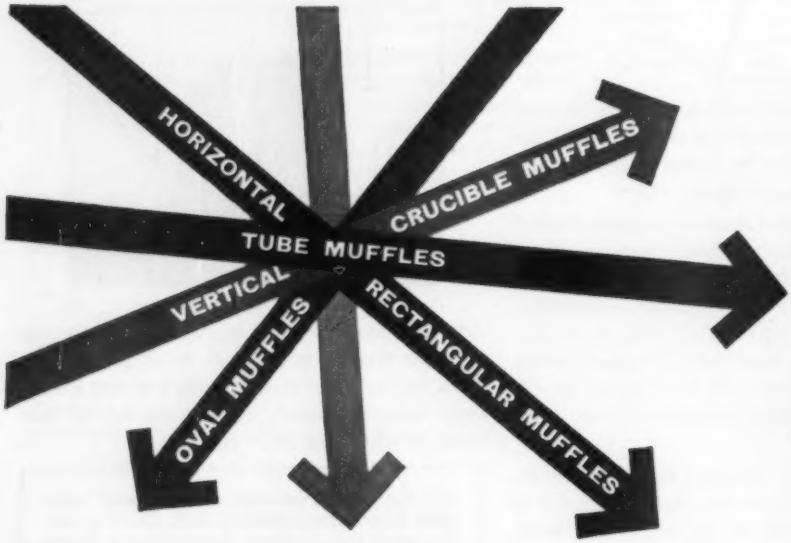

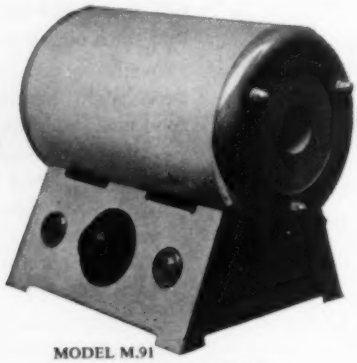

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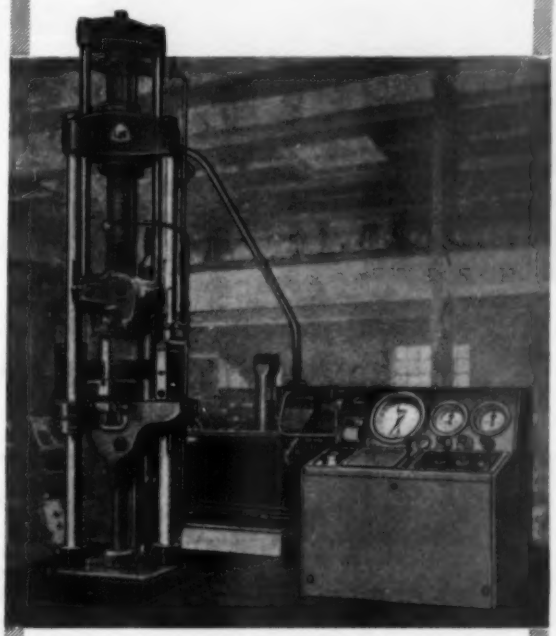

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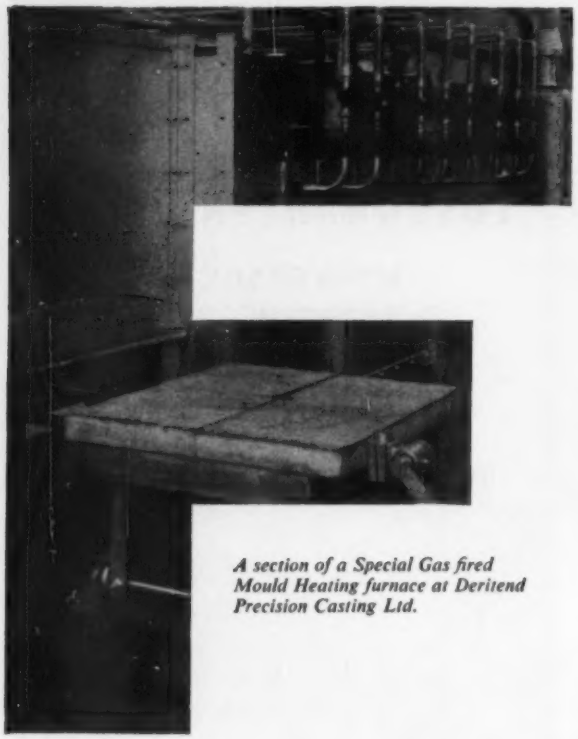

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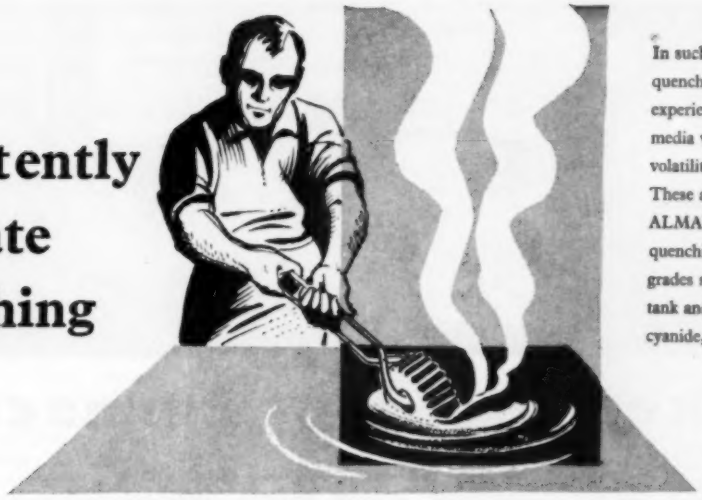

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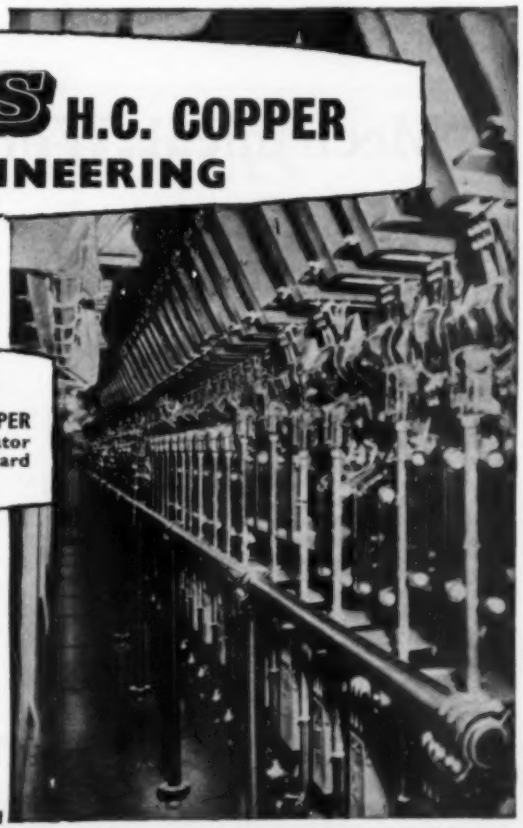

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The photograph on the right shows the rear view of the feeder section of the main switchboard, 69′ in length, manufactured by **Whipp & Bourne Ltd.** For this section and also the generator section, Bolton's supplied 21 tons of h.c. copper.

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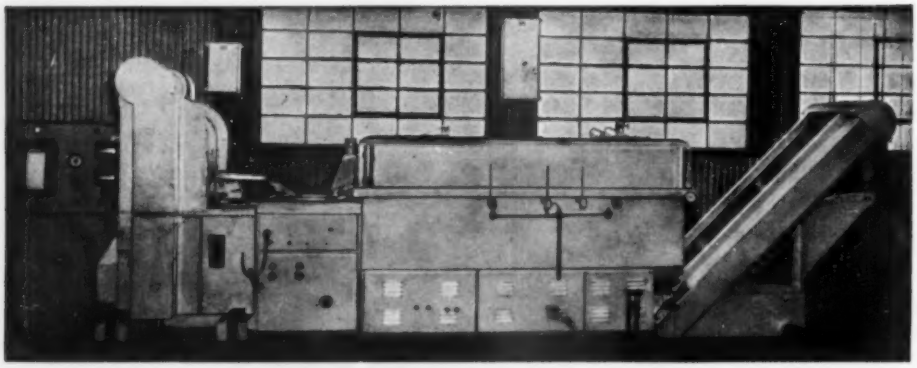

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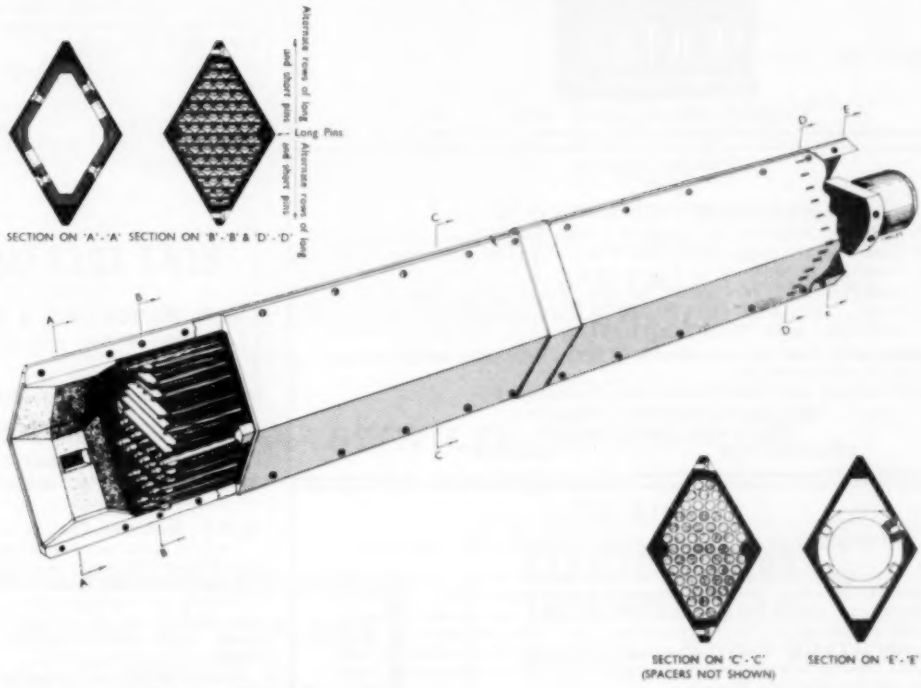
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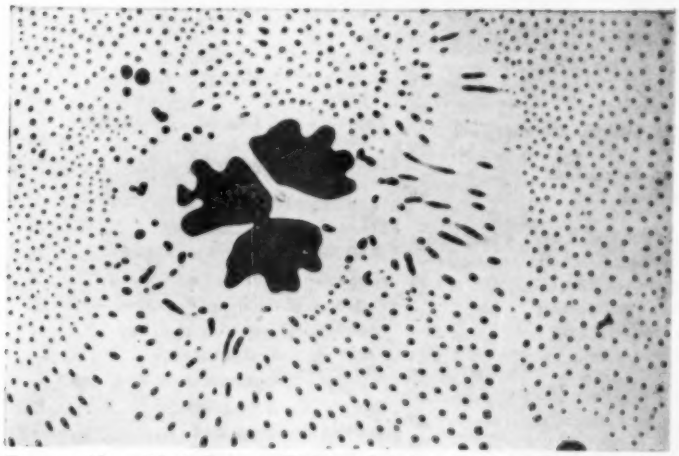

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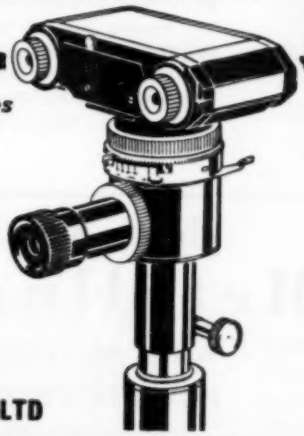

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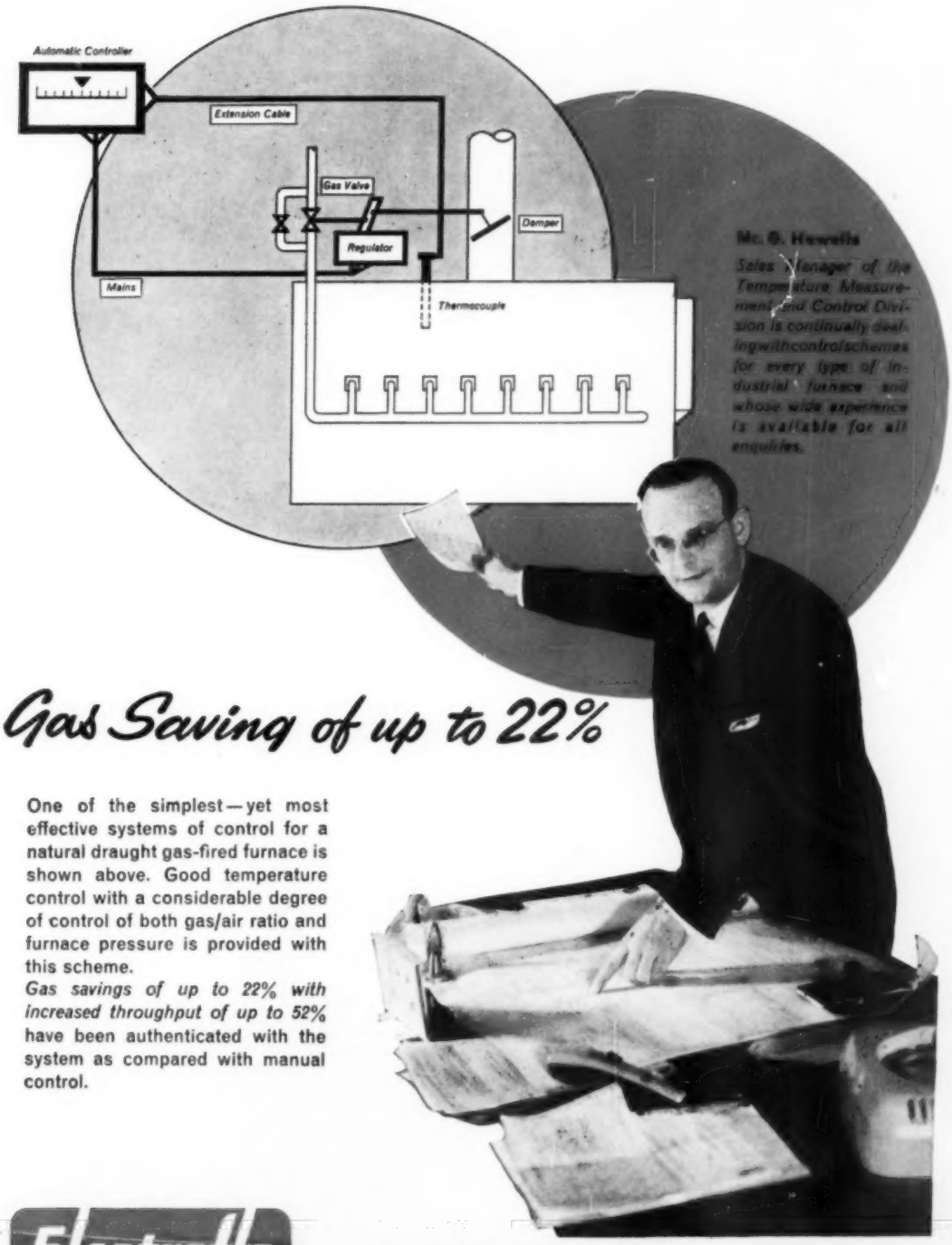
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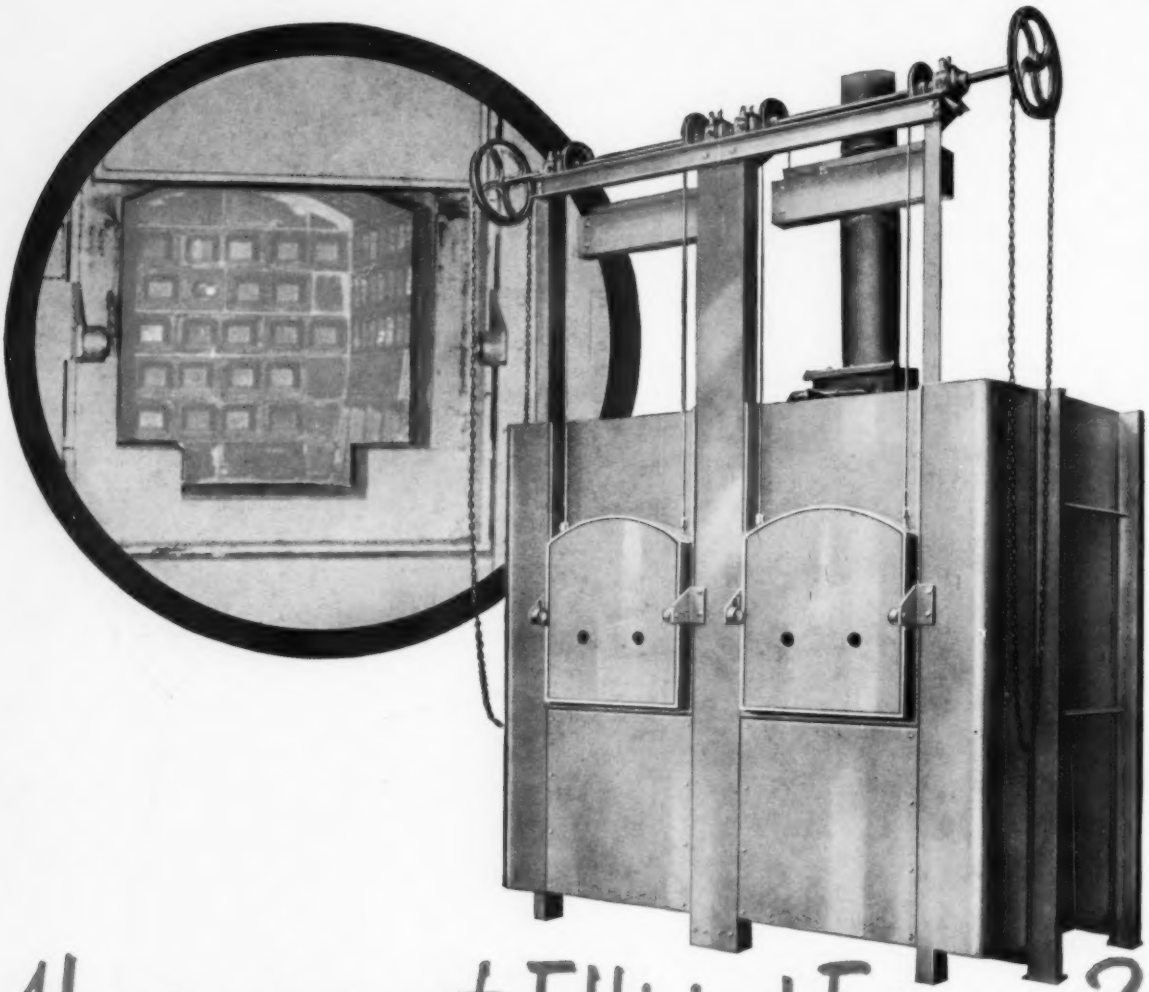

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